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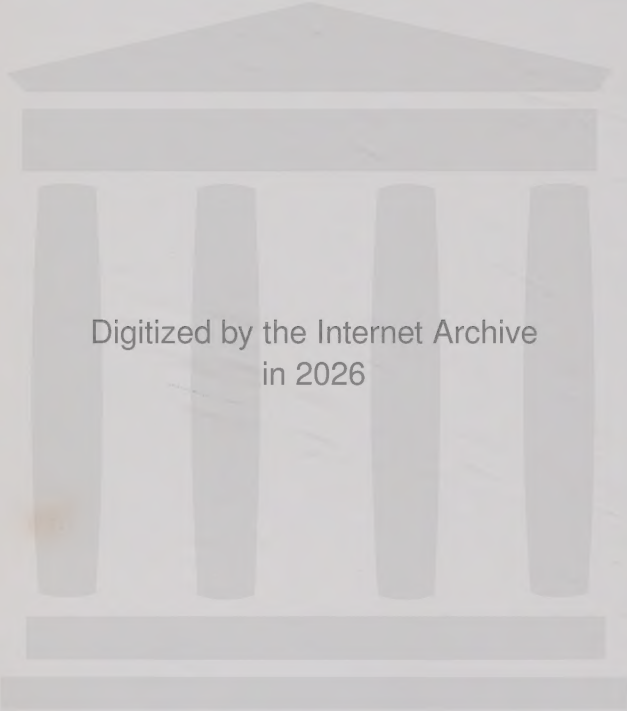
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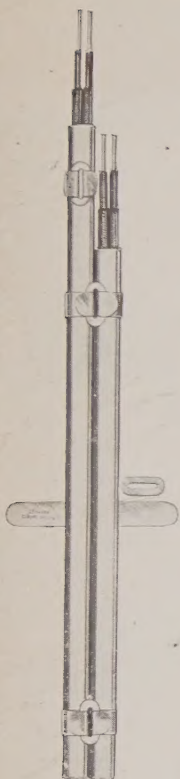
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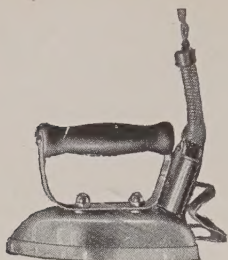
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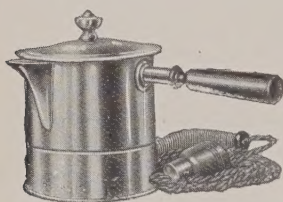
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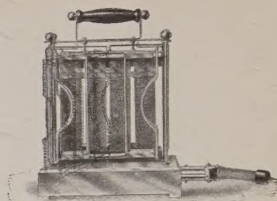
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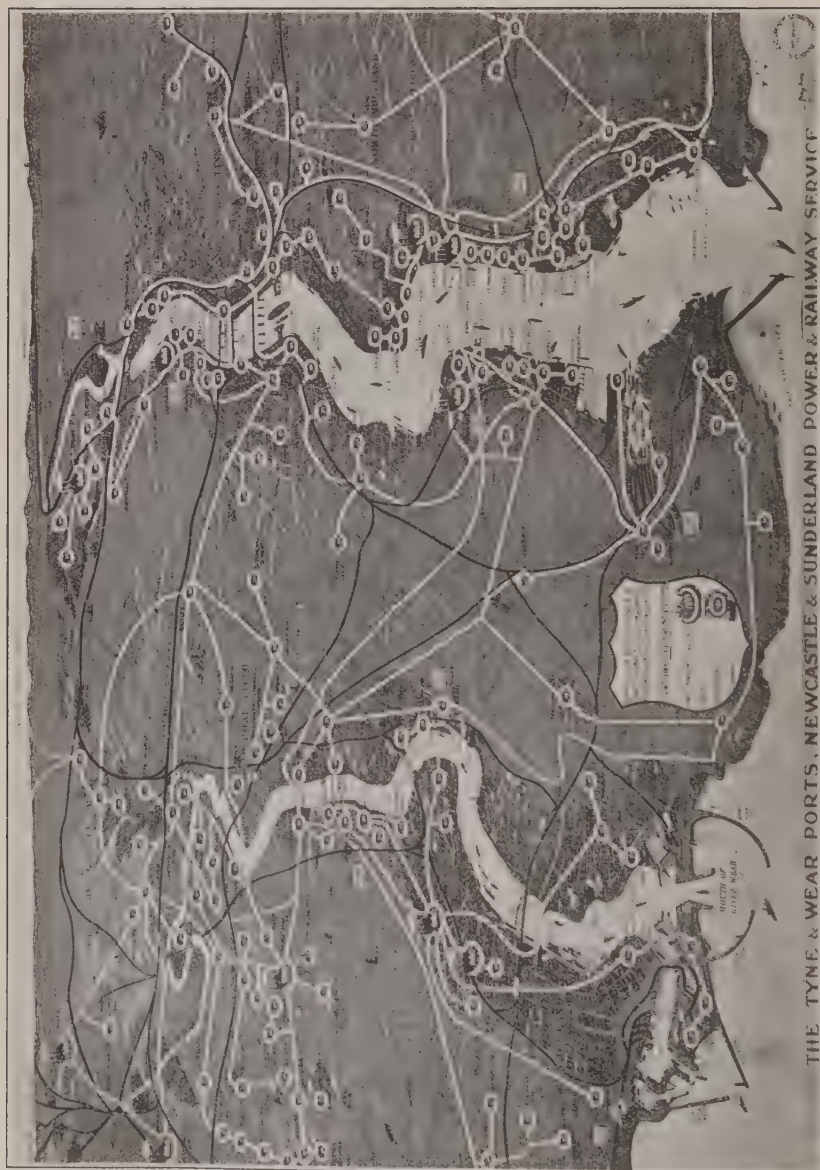
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THE ALL-ELECTRIC AGE



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THE ALL-ELECTRIC AGE

BY

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"THE ELECTRICAL INDUSTRY," "ELECTRICITY IN LOCOMOTION," ETC.

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CONTENTS

CHAPTER	PAGE
I. THE BIRTH OF THE ELECTRICAL INDUSTRY . . .	I
II. HOW ELECTRICITY IS MADE	8
III. PIONEER DAYS IN ELECTRIC LIGHT AND TRACTION .	18
IV. ELECTRIC TRACTION ON ROADS	31
V. INDUSTRIAL USES OF ELECTRICITY.	53
VI. THE GROWTH OF CENTRAL POWER STATIONS	76
VII. THE COMING OF THE SUPER-STATION	95
VIII. MODERN ELECTRIC LIGHTING	114
IX. ELECTRIC HEATING	151
X. ELECTRIC COOKING	173
XI. THE LABOUR-SAVING HOME	188
XII. ELECTRICITY AND HEALTH	207
XIII. ELECTRICITY IN COMMUNICATION	218
XIV. THE FUTURE	224
INDEX	235

LIST OF ILLUSTRATIONS

HALF-TONES

A foretaste of the All-Electric Age	<i>Frontispiece</i>
	PAGE
An electric train on London's latest electrified suburban railway for the extension of the Central London Railway to Ealing. Current is supplied to the trains by the third rail between the running rails	27
Goods train on the Newport-Shildon section of the Great Eastern Railway, hauled by electric locomotive. Overhead wires are used to convey the current, which is collected by sliding bows carried by the locomotive	29
Double-decked electric trolley omnibus put into service by the Bradford Corporation. This vehicle can manœuvre freely from side to side, and forms a compromise between the electric tramcar and the motor omnibus	33
Small electric battery trucks are largely used for hauling loads in railway stations, docks, and factories. This photograph was taken in Euston Station, London, during the war, when the trucks were driven by women	39
One of the fleet of electric lorries used by the Cleansing Department of Birmingham for the collection of house refuse. This vehicle is fitted with electrically operated tipping gear	45
Electric drive in factories. A typical example of "individual drive" where each machine is fitted with its own electric motor, thus eliminating shafting and belting and giving convenience in control and economy in power	57
An electric crane and lifting magnet combined. The mushroom-shaped magnet holds a large steel ball which, when the current is switched off, falls on the heap of scrap-iron and smashes the large pieces into small fragments convenient for melting down in the furnace	62
Electrically driven transporter capable of handling 150 tons of coal per hour	63
Electric motor and tool in one. The portable electric drill which does its work in any position. Current is conveyed to it through the flexible cable	67
An electric welder at work on pots and pans. Here it is shown fixing a handle to a saucepan. Some samples of its work are seen in the foreground	69

One of the large electric steel-making furnaces which did such excellent work during the war. It is capable of melting twelve tons of steel	71
An example of how readily electric power may be applied to isolated machines. A pneumatic power hammer driven by an electric motor	73
How electric power is conveyed by means of overhead wires. The deep valley is traversed by a single span about one-third of a mile long. The wires form a main transmission line from a power station to large industrial users, and carry about a thousand horse-power	97
Interior of a modern electric power station, showing several sets of large steam turbine-driven electric generators. A portion of the condensing plant is visible	112
An example of scientific industrial lighting, in which the lamps are arranged in metal reflectors, which prevent glare and distribute the light evenly over the working plane. This photograph was taken by the light of the lamps	127
Drawing-room illuminated on the indirect system in which all the light from the lamp is thrown on to the ceiling and reflected therefrom in a diffused glow all over the room. In the fire-place is an electric fire, specially designed to give a pleasant flickering effect	137
A striking example of the wonderful effects which can be obtained by various modes of electric lighting. The ground floor is illuminated by concealed lamps, giving a stage effect	145
The modern method of shop-window lighting is by means of concealed electric lamps fitted with special reflectors which diffuse the light over the goods to be displayed. The effect is a bright picture in a dark frame. This photograph was taken by the light from the windows themselves	149
Electric table cookery. The appliances here shown on the table include a grill, kettle, dish warmer, milk warmer, toaster, and coffee percolator	183
Standard electric cooking outfit for the home. This includes an oven, a double boiling plate, a grill, and a water heater. Each piece of apparatus is controlled by switches on the wall. It should be noted that everything stands on a table at a convenient height	185
Electric vacuum cleaners can be used not only for carpets but, by means of simple attachments, for removing dust from upholstery, bedding, and curtains	195
Another form of electric washing machine and wringer. The motor operating the washer and wringer is started and stopped by the handle at the side of the machine	201
How electricity is conveyed cheaply to remote country districts. These overhead wires carry enough power to light and operate a farm	225

LINE ILLUSTRATIONS

	PAGE
Lighting Load Curve	19
Glynde Telfer	65
Power and Lighting Load Curve	88
Power and Lighting Load Curve (Glasgow)	89
Power and Lighting and Traction Load Curve	90
Comparative Sizes of Steam Turbines and Reciprocating Engines	93
Electric Lamps	117
Types of Distribution of Light	129
Types of Reflector	133
Factory Lighting Fittings	141
Lamp Radiator	152
Modern Electric Fire	155
Small Electric Fire	158
Electric Kettle	159
Electric Flat Iron	165
Hot Plate	179
Chafing Dish	179
Coffee Percolator	180
Electric Toaster	181
Suction Cleaner	193
Dish Washer	197
Clothes Washer	199
Sewing Machine	204
Electric Fans	209
Hot-Air Machine	211

ACKNOWLEDGMENTS

Grateful acknowledgments are due to a number of electrical firms for the illustrations in this volume :—

	PAGE
Messrs. Merz and McLellan	Frontispiece, 29, 112
Underground Electric Railways Company of London	27
Bradford Corporation Tramways Department	33
Gillespie Partners and Electricars, Limited	39
Ransomes Sims and Jefferies, Limited, and the Cleansing Department of the Birmingham Corporation (Mr. James Jackson, superintendent)	45
General Electric Company, Limited	63, 183
British Thomson-Houston Company, Limited	57, 127, 137, 149
Harryat and Place	62
Choley and Company, Limited	67
British Insulated and Helsby Cables, Limited	69
Mather and Platt, Limited	73
Callender's Cable and Construction Company, Limited	97
British Electric Transformer Company, Limited	185
(Makers of " Tricity " electric cooking and heating apparatus)	
Edison Swan Electric Company, Limited	195
Edison Electrical Company, Limited	201

THE ALL-ELECTRIC AGE

CHAPTER I

THE BIRTH OF THE ELECTRICAL INDUSTRY

WHEN Michael Faraday was showing his famous electrical experiments to people who were not familiar with the ways of science, he was frequently asked, "What is the use of it?" On such occasions he was fond of following Franklin's example and replying by another question, "What is the use of a baby?"

When a baby is born, no one can say whether it is destined to make its name immortal or to pass among the unremembered multitude. In the same way a man of science who performs a successful experiment cannot tell whether he has merely added another grain to the hill of knowledge or whether he has produced the germ of some revolution in human thought, some industry which will mark a new epoch in human progress. Faraday was well aware that the discoveries made in electricity and magnetism were of great scientific importance. Although the apparatus he used was simpler and more crude than the instruments that many a boy plays with in his workshop, he certainly felt that he was unlocking the inner secrets of Nature. But even he, with all his genius, could not have foreseen a fraction of the triumphs which the child of his brain would achieve.

Faraday died in 1867, when the electric telegraph, electroplating, and the illumination of lighthouses by arc lamps were practically the only examples of electricity in the service of man. All that we speak of to-day as "the electrical industry"

had still to come—the production of electricity on the large scale, the lighting of streets and buildings, the driving of machinery and vehicles, the telephone, telegraphy and telephony without wires, the medical applications of electricity, electric furnaces, electro-chemical processes, electric heating, electric cooking, and a hundred other examples of “applied electricity.” The work which Faraday pursued in poverty, and under the shadow of neglect from many of the leaders of science, was the starting-point of that mighty development.

There is an element of pathos in the reflection that he did not live to see even the first green shoots from the seed he sowed. In the year 1906 Lord Kelvin, when unveiling a memorial tablet to Faraday, said that “how much Faraday would have been delighted with the telephone some of us can imagine. How much, too, would he have delighted in the application of electricity to the transmission of power.” Nevertheless, he had his reward. The discovery of a scientific law brought him as much joy as any vision of the electrical industry could have inspired.

In the following pages a description is given of the changes which electricity has produced, and will yet produce, in social, industrial, and domestic conditions. Electricity is dealt with as a factor in civilisation, not as a science or a branch of engineering. The world is apt to accept benefits without more than a passing thought for the men who laboured to make them possible; but, as the increase of electrical benefits depends to a large extent upon the encouragement of science and engineering, it is as well that the chief source of electrical progress should be recognised at the outset.

Faraday worked in the realm of “pure science,” and his name is linked with those of men who, before and since his day, have pursued knowledge for its own sake. So keen are some of them on the “purity” of their quest that they almost resent the desire of the matter-of-fact man to find something useful in their discoveries. They are like the nobleman who exalted the Order of the Garter because there was “no d—— merit about it.” But civilisation does not live by pure science alone, and it owes a debt not only to the galaxy of investigators among whom Faraday shone so

brightly, but also to the inventors who designed electrical machinery and to the manufacturers who produced it for everyday service. Even the financier, who risked his money—and often lost it—to make electricity available, should not be forgotten. All these groups, with their various motives and aims, have combined to lay the foundations of the all-electric age.

These foundations were laid with amazing rapidity. The whole span of electrical enterprise—using the words in their usual meaning, apart from telegraphy—stretches back little further than forty years. In 1880 the electric incandescent lamp became a commercial article and made domestic lighting possible. In 1882 the first Electric Lighting Act was passed, laying down the regulations by which companies or municipal authorities might open up the streets to lay mains for the public supply of electricity from central stations. In 1883 the first electric railway—from Portrush to Giant's Causeway—was opened ; and to the same year belongs the Brighton Beach Railway in its original form, with the track below high-water mark. Electric tramways date from about ten years later when, also, serious attention began to be given to the driving of factories by electric power. Marconi's first successful demonstrations of wireless telegraphy were given in the year 1898.

Each of these dates marks the beginning of a new branch which grew so quickly that it soon became entitled to rank as a new industry. Electrical engineers in the 'eighties could quite comfortably master the whole range of electricity in action. They could speak familiarly of telephones (invented in 1876), telegraphs, electric light, electric traction, and all the other sections upon which inventive genius and capital were being expended. But to-day everyone in the industry is compelled to specialise in one section and to be content with only a nodding acquaintance with the problems of specialists in other sections. Thus we have, in the electrical industry, many men still active who can easily recall the complete story of the pioneering days, and thousands of others who find their life's work in some minute subdivision of electrical research or manufacture unknown and unimagined in the 'eighties.

It is to this swift evolution in so many ever-changing directions that the electrical industry owes its quality of youthfulness. Had it progressed steadily along a straight line after the manner of the steam engine, it would have been regarded as mature many years ago. The public, however, has always expected the industry to give much more in the future than in the past. Electrical engineers smile, with a touch of resentment, at the eternal phrase: "Electricity is in its infancy." When electric light undertakings were inaugurated in any part of the British Isles it was practically certain that the Mayor would declare, after the Mayoress had switched on the current, that electricity was in its infancy. Custom dies hard in the municipal world, and it is only by a great effort of restraint that a layman can deliver a speech about electricity without echoing the phrase.

From one point of view it is preposterous to describe as an infant a great industry which, in Great Britain alone, directly represents a capital of close on £500,000,000, while in all parts of the world its operations profoundly affect the daily lives of millions of people. Again, it is a formidable infant whose existence is so complicated that those who spend their days in studying one fraction of it are at the end more impressed with their ignorance than with their knowledge. Yet it is the faith of every electrical enthusiast that the wonders of the last forty years are only a prelude to the wonders to come. The time is yet far off, and may never arrive, when it will be said that electricity has made its ultimate gift to humanity and that no more remains to be done beyond making the benefits of the gift universal. Hitherto every electrical discovery has been the germ of many new discoveries or applications; every improvement has opened up new possibilities of service to industry, security, or health. Remembering that progress has been more and more rapid as knowledge and achievement developed, no one anticipates the day when the unfolding will be arrested.

It is interesting to search for a reason why electricity is always seen through this atmosphere of infinite possibilities. Professional enthusiasm does not explain the phenomenon, because electrical engineers are for the most part so absorbed

in the specific work before them that they are not aware of the atmospheric effect which they themselves help to create. The explanation probably lies in the fact that electricity itself is fundamental. When we analyse "matter" and "energy" we find electricity. The atom—once regarded as an indivisible grain of solid substance—is now conceived as a complex system of revolving electrons, or infinitesimal charges of electricity. In radium we have an example of the system breaking up and throwing off its charges of electricity in the process. The special properties of the different elements are regarded as the outcome of various numbers and arrangements of electrons. Thus the ultimate "stuff" of the universe is nothing else than electricity; and in the last resort all science is the study of electricity.

Here, also, we find the reason why electricity has earned the reputation of being a "protean sprite." Just as the unity of nature resides in electricity, so we find electricity concerned in all the diverse phases of nature and art. One and the same form of energy gives us light, heat, and power; it sends waves through the ether and translates them into articulate sounds or visible signals; it separates the elements in a metallic solution and deposits the metal; it takes shadowgraphs of our bones; it stimulates the action of nerves and encourages the growth of plants; it radiates from the sun and circulates through the earth; it drives the huge steel rolling mill and conveys heat through our tissues; it melts tons of metal in furnaces and cooks our food in dainty table appliances; it is our universal messenger and a universal transport agent, propelling trains, steamships, aeroplanes, and street vehicles. Directly or indirectly it is at work in almost every direction to which we turn; and in that sense we may say that the all-electric age has already arrived.

Nevertheless, we have still some distance to travel before the proven benefits of electricity are realised in practice. Many people consider that it will be a long, long time before electric light, electric power, electric heating and cooking, electric traction, and the various other established uses of electricity will become anything like universal in even the most highly civilised communities. Progress, to those who float with the

stream, seems slow. In electrical affairs, however, we have seen that the stream does in reality flow swiftly. In the life of a nation forty years are as a day ; and when we look back upon what has been done since 1880 by a comparatively small band of electrical pioneers, working under great difficulties, we gain a very lively vision of the advance which the next generation will witness. The electrical engineers of to-day inherit the wealth of the pioneers ; they are much more numerous and much better equipped. Thus the stream of electrical progress is certain to flow with increasing swiftness and volume through every department of human activity.

In composing our picture of the all-electric age we assume nothing that electricity has not shown itself capable of doing. It is probable, if not certain, that fresh discoveries will be made within the next ten or twenty years ; and it is possible that some of them will quite transform the picture. Speculation on these lines is, however, of little value at the moment. We take applied electricity on the territory it has already marked out for itself, and we merely assume that it will consolidate the conquest. Where many people make a certain use of electricity, to-morrow will see everybody enjoying the service ; where a few have proved the value of a particular application, many will soon follow suit ; and where experimental effort has been successful, a commercial proposition will be established. Working on these lines we shall achieve a realistic picture or, rather, a working programme which any community can carry out if it enjoys a cheap and abundant supply of electricity.

In order to understand what electricity can do, it is necessary to know a little about how electricity is produced and how it is applied to various purposes. There is a general impression that these things are too difficult and obscure for anybody who has not gone through a long course of initiation. The electrical engineer is regarded as the high priest of an esoteric cult ; and indeed his language, when he attempts to explain an electrical mystery to a non-electrical mind, tends to support the illusion. Several books have been written to interpret the mystery to the lay reader, both young and old ; and to these anybody may turn who wants to make a serious

excursion into the first principles of the subject without going through a formal course of study in electricity and magnetism.

In our own pages we shall deal with the simple and most essential facts about electricity which concern the workaday world ; and we shall try to present them in a form which will be readily understood. After all, an electric power station is not, in its broad practical aspects, more complicated than a motor-car ; and to-day thousands of people who have no knowledge of physics or mechanics treat the mechanism of a motor-car as a familiar friend. The apparatus by which electricity is applied to the service of man, both in industry and in the domestic sphere, is simplicity itself. Moreover, our main concern is with the service rendered and its influence on the material well-being of the nation. These are matters which can be explained with the use of very few of the strange words in which the electrical engineer is compelled, as the representative of a new science, to clothe his thoughts on technical subjects.

CHAPTER II

HOW ELECTRICITY IS MADE

ONE of the standard anecdotes of the electrical world relates to a student whose Professor asked him the simple question : "What is electricity ?" After an unusually long period of embarrassment the student confessed that he had forgotten. "What a tragedy !" exclaimed the Professor ; "here is the one man in the world who knew what electricity is, and he has forgotten."

This story is more than an apology for beginning to describe the all-electric age without defining electricity. It conveys a hint that one may know a vast amount about electricity without being able to say what it *is*. The mysterious nature of electricity has, indeed, been rather overdone, and people have troubled themselves too much over the fact that electric charges and electric currents are in themselves invisible and apparently intangible. Electrical engineers, who are practical people, do not worry about invisibility and intangibility. They know what electricity can do, and they know that they can measure its attributes—its quantity, its pressure, its energy—with the highest possible degree of accuracy. Science, as Lord Kelvin said in effect, is measurement ; and he not only established the principles on which electrical phenomena could be measured, but he devised instruments for doing it. To-day, when a man of science desires to measure any effect with precision, he is happy if he can translate it into something electrical. We know the efficiency of an electrical machine much more accurately than we know that of a steam engine, or a motor-car, or many another commonplace mechanism. Thus the thing which in itself seems most elusive to our senses is the most reliable guide to what is going on among

the solids, liquids, and gases that we can see or weigh or analyse.

On the other hand, although electricity can be measured with assurance and controlled with certainty, it does not readily lose its traditional power of inspiring wonder. Professor Fleming, who has spent his life in electrical investigations, and especially those connected with wireless telegraphy, has related that he is still touched with awe when a wireless receiver reproduces the message sent from a distance by means of electrical waves. Something of the same quality resides in even the most ancient of electrical experiments. When amber is rubbed with silk it becomes able to attract fragments of paper. What could be more commonplace than this first lesson in electricity? Nevertheless, it still seems to open the door to undiscovered secrets of Nature.

The rubbing of the amber involves work; and it is by virtue of that work that the amber becomes electrified. In attracting the fragments of paper the amber spends some of its electrical energy. That is to say, mechanical energy is first transformed into electrical energy, which is then transformed back again into mechanical energy. Similar transformations are going on around us incessantly. The heat of the sun changes water into vapour, which rises, condenses, and falls as rain which swells river courses; these river courses may be utilised to drive water-wheels generating electricity which can be transformed into heat and light. The food we eat passes through chemical processes which unlock the energy required to warm our bodies, rebuild our tissues, and drive the machinery of thought. Electricity is one of the various forms of energy which take part in this continuous transformation scene. It can be readily converted into heat, light, sound, chemical energy, and mechanical power, and it is most conveniently produced from the last two forms.

The electric battery, which was invented by Volta towards the end of the eighteenth century, is an apparatus for transforming chemical energy into electrical energy. When a plate of copper and a plate of zinc are placed in a bath of dilute acid and connected together by a wire, electric current flows along the wire and through the battery. The energy of this current

is maintained at the expense of the materials in the battery, the zinc being "consumed" much as the coal is consumed in an electric power station. During the nineteenth century attempts were made, by coupling large numbers of improved batteries, to obtain a lasting source of powerful electric currents, but they were not very successful. To-day the electric battery is used only where feeble currents are required intermittently, as in telegraph or telephone work, or for ringing electric bells, or for lighting small pocket "flash lamps." The electrical industry proper dates from the discovery of an efficient means of transforming mechanical energy into electrical energy.

Following upon Faraday's discovery that electricity and magnetism were essentially one and the same thing, "magnetic machines" for producing electricity were invented. When a coil of wire is moved near the poles of an ordinary magnet, force has to be exerted to overcome the influence which the magnet has on the moving coil. This force is transformed into currents of electricity in the coil, the strength of the current depending upon the strength of the magnet and the speed of rotation. The magneto used on motor-cars is based upon this principle, which has also become more or less familiar through the "medical battery" used for producing the light currents required in certain forms of electrical treatment.

By using a large number of magnets and driving the machine by a steam engine, sufficient current was produced for an arc lamp. About the middle of last century machines of this type were made for lighthouse purposes. They were, however, so costly and inefficient that, in 1863, Lord Kelvin wrote, "I believe a large voltaic battery will be more economical than any electro-magnetic machine." The essential drawback of the machine was the restricted power of the permanent steel magnet; and accordingly many inventors strove to evolve a type of magnet which would be free from this limitation. They found it in the electro-magnet which, in its simplest form, is a bar of soft iron magnetised by electric current flowing in a coil of wire round it.

It is tempting to plunge into details of the early machines which embodied this change and to tell the story of how

various minds, working more or less independently, hit upon the designs which led eventually to the giant electric generators of to-day. But we must confine ourselves to the broadest indications of how the electric generator or "dynamo" works.

To produce a powerful electro-magnet it is necessary, among other things, to obtain a strong electric current. But as such current was the very thing that was in request, the problem was rather puzzling. The difficulty was got over by starting with a small amount of magnetism in the machine and gradually building it up, the building up being done by the power used to drive the machine. Speaking of another kind of electrical machine in which a parallel principle was embodied, Lord Kelvin said that it was "an easy-going electrical machine built on the principle of the Successful Merchant who, commencing life with a capital of $\frac{1}{2}$ d., had, after persevering industry, accumulated the handsome sum of £1, and continued to go on increasing it at compound interest." The dynamo likewise starts with a halfpenny worth of magnetism and adds to it until the limit for which the machine is designed has been reached.

The outcome of the invention of the dynamo was that a practically unlimited source of electricity became available. Electro-magnetic machines with permanent magnets took over horse-power to produce enough current for a single arc lamp; to-day there are electric generators of over 60,000 horse-power supplying a large population with electricity for industrial and domestic purposes. The earliest dynamos, however, were small affairs. In 1879 an electrical engineer, who was then eminent and rose to still greater eminence, stated that the "electric light is only economical when one machine is used to produce a single light." Other engineers were more daring. The typical electrical installation of those days was a small steam engine driving a dynamo to supply about half a dozen arc lamps. One of the best customers of the early dynamo maker was the travelling circus, which found arc lighting safer and more brilliant than the paraffin flare. Railway stations, open spaces, and public halls were the other chief places in which electric light had become familiar before the year 1880.

Small and primitive as these installations were, they were the direct parents of the gigantic and complex electric power stations of to-day. Both show the same essential features—the “prime mover” or engine which drives a dynamo or generator of electricity; the wires leading away from the centre of generation to the place where the electricity is wanted; and the apparatus in which the electricity is used to do work, such as producing light or operating a machine. What the pioneer plant did in a retail fashion over a radius of a few dozen yards the modern plant does in a wholesale manner over tens or even thousands of square miles.

It is very interesting to trace the stages by which the portable circus lighting equipment grew to the “super-station” which may cost two million pounds to build and equip. The growth was really forced by the appearance of new demands for electricity. Before the year 1880 the arc lamp represented the only use of electricity with which the public was directly concerned. The use to which this type of lamp could be put was, however, restricted by the very brilliance of the light. When two pencils of carbon are brought together to complete an electrical circuit the resistance which the current encounters at the point of contact produces intense heat. The carbon tips, in fact, become white-hot; and when the tips are drawn apart for a short distance the current leaps across in a bridge or “arc” of white-hot carbon vapour. Thus the arc lamp is really an apparatus for converting electricity into heat and light. Its main drawback is that, while it will give a very economical light equal to one thousand candle-power, it will not supply the modest illumination required for an ordinary room.

For many years inventors worked at the problem which was then known as the “subdivision of the electric light.” The solution was reached at practically the same time in this country by the late Sir Joseph Swan and in America by T. A. Edison. Both used a very thin filament of carbon in a bulb from which the air had been withdrawn. One of the elementary laws of electricity is that the thinner the wire along which current is flowing the higher the resistance to the passage of the current, just as a narrow pipe offers a greater resistance than a wide one

to the flow of water. By making the strand of carbon exceedingly thin, the resistance becomes so high that the carbon rapidly becomes white-hot. By excluding air the carbon is prevented from burning away. This is the essential character of the electric incandescent or "glow" lamp out of which the electric lighting industry was born.

Its birth was a scientific marvel, and it was accompanied by marvels of another sort on the Stock Exchange. As soon as the "subdivision of the electric light" was announced there was a slump in gas shares and a boom in the shares of companies formed to exploit the new lamp. The City, in short, went mad over electric light, and it had a very sharp and sorry repentance. Many years of difficulty were to pass before the supply of electric light became a profitable business; nevertheless, that early fever of optimism was a very striking tribute to the fascination which anything electrical holds over the mind of man.

The first installations on which the glow lamp was used were on a very similar plan to the arc lamp installations. That is to say, a small engine was used to drive a dynamo sufficient only for a few dozen lamps—enough for a single building. Lord Kelvin claimed that "the first house on this planet in which the whole lighting was done by electricity was his house in the University of Glasgow." The rule given to the workmen who carried out the installation was: "Go through the whole house; wherever there is a gas burner put in an electric light." There were 106 gas burners; and there were 106 electric lights in that house about the end of the year 1881." Another interesting picture from the same year is that of Lord Kelvin confined to bed and enjoying the astonishment of visitors when they caught sight of a Swan electric lamp fastened to the window-curtains by a safety pin.

This particular lamp was supplied with current from a storage battery or accumulator. The liveliest hopes were then entertained about the value of this appliance in the supply of electricity; and although these hopes have since been somewhat subdued, the storage battery has proved so useful in this and other directions that a word of description is necessary. As most users of motor-cars know, a storage battery has first

to be charged with electricity. The electrical energy put into it is converted into chemical energy ; and when the charged battery is put into operation its chemical energy is converted back into electricity. Thus it acts as a portable reservoir of electric current. Some of its early apostles had visions of electricity being delivered from house to house " in bottles," like milk ; and even within recent years this quaint notion has cropped up at intervals. But the useful field for the storage battery to-day lies chiefly in country house lighting, in electric stations where a " stand-by " source of electricity is wanted during hours of heavy demand, and in the propulsion of vehicles.

When the house-to-house distribution of electricity was undertaken it was not by carts filled with storage batteries but by copper wires carrying electric current. From the first stage of a single building to that where several buildings were supplied from the one plant the step was a short and natural one, but it was of immense importance. Electric light installations became " central stations," and they also became the subject of legislation. In order to lay electric cables from house to house it was necessary to open up the streets ; and the right to open up streets is reserved to municipal authorities, gas companies, water companies, and other people armed with " statutory powers."

Legislation is a dry subject, and the story of electrical legislation is particularly depressing. Nevertheless, it has a moral for those who look forward to an all-electric age ; and some of the melancholy tale must be told in order to reveal the obstacles which have stood, and are still attempting to stand, in the way of electrical progress. When the industry was really in its infancy the Government set to work to regulate it. An inquiry was held into what the electrical industry could do and how it ought to be made to do it. As a result the Electric Lighting Act, 1882, was passed.

This Act encourages the belief that, if the road to hell is paved with good intentions, it is those which are carried out and not those forgotten which form the main part of the pavement. Nothing could exceed the benevolence of the Government of those days ; it was benignly determined to do

the best for electric light, for the promoters, for the public, and for posterity. It decided that each electric light undertaking should be confined to a single municipal area, that any company seeking to supply electric light in any area should first get the consent of the local authority, and that at the end of twenty-one years the local authority should have power to buy up the whole undertaking at the "then value" of the plant, without any allowance for goodwill, or anything else usually taken into account when a business is sold as a going concern. The prices which could be charged for electricity were limited, and many other restrictions were imposed.

All these things were done to protect the public. And they were so effective that for six years the public had no electric light at all. Nobody would lend a penny to an enterprise that was liable to be sold up at scrap-iron value when it came of age. These six years were needed to convince the Government that it had made a fatal mistake, and to induce it to amend the Act by making the period of tenure forty-two instead of twenty-one, and by introducing one or two other changes. A great deal used to be heard about the backwardness of Great Britain in electrical matters; and people who knew nothing of these Acts were ready to blame British engineers and capitalists for lack of enterprise. It is really the Government, however, that ought to be pilloried. Even the amending Act of 1888 was only a half-hearted repentance for a legislative crime; and during the succeeding years the men engaged in electrical work pleaded incessantly for more freedom to develop the supply and applications of electricity. Time and again the Government promised reform—and did nothing. The electrical industry had, in fact, lost hope when the War produced Government and a nation enthusiastic for reconstruction. As a result we have now the Electricity (Supply) Act, 1919, embodying the long-delayed charter.

The features of the new Act fall to be described later. For the present we are concerned with the first stage of progress after the Electric Lighting Act, 1888, had made enterprise possible. Electrical science and electrical engineering had gone ahead, especially in America and on the Continent, during the six dead years; and after the revival the first

electric light stations to be erected were on a larger scale than would have been attempted in 1882. They were still, however, comparatively small affairs ; the mains which carried the current extended no more than a mile or two from the source of supply. The parochial idea which had inspired the authors of the Electric Lighting Acts seemed quite broad enough for the electrical engineer. Tucked away in some by-street near the centre of the city was a little electric light station, with engines of 100 horse-power or so and with a network of mains along the principal streets supplying electricity for lighting public buildings, shops, and the houses of the wealthier classes. The business started in a modest way and developed slowly year by year. When the original generating set showed signs of being overloaded, another was placed alongside, and so on until the station was fully occupied. Then a new station would be built on a more commodious site and the old one scrapped.

Thus the infant electric light industry grew stronger by crawling. To some of those immersed in the daily work of the industry nothing more ambitious may have appeared possible. But there were others whose outlook was broader and whose vision was more penetrating. They foresaw the time when these little electric light stations would give place to large electric *supply* stations, flinging their mains far and wide and distributing electricity for operating tramways and railways, driving machinery, and for a hundred and one other purposes which would make the demand for electric light seem a mere trifle. Even so far back as 1878 this prophecy had been framed. At a meeting of the Institution of Civil Engineers in that year, when improvements in the dynamo had been discussed and when Dr. Siemens had referred to the possibility of transmitting electricity to a distance, Lord Kelvin, speaking almost on the spur of the moment, gave this remarkable sketch of the all-electric age :¹

“ He believed that with an exceedingly moderate amount of copper it would be possible to carry the electric energy for one hundred, or two hundred, or one thousand electric lights

¹ *The Life of Lord Kelvin*. By Silvanus P. Thompson, Vol. II.

to a distance of several hundred miles. The economical and engineering moral of the theory appeared to be that towns henceforth would be lighted by coal burned at the pit's mouth, where it was cheapest. The carriage expense of electricity was nothing, while that of coal was sometimes the greater part of its cost. The dross at the pit's mouth (which formerly was wasted) could be used for working dynamo-engines of the most economical kind, and in that way he had no doubt that the illumination of great towns would be reduced to a small fraction of the present expense. Nothing could exceed the practical importance of the fact to which attention had been called : that no addition was required to the quantity of copper to develop the electric light at a distance. The same remarks could apply to the transmission of power. Dr. Siemens had mentioned to him in conversation that the power of the Falls of Niagara might be transmitted electrically to a distance. The idea seemed as fantastic as that of the telephone or the phonograph might have seemed thirteen months ago ; but what was chimerical then was an accomplished fact now. He thought it might be expected that, before long, towns would be illuminated at night by an electric light produced at the pit's mouth or by a distant waterfall. The power transmissible by the machines was not simply sufficient for sewing-machines and turning-lathes, but, by putting together a sufficient number, any amount of horse-power might be developed. Taking the use of the machines required to develop 1000 horse-power, he believed it would be found comparable with the cost of a 1000 horse-power engine ; and he need not point out the vast economy to be obtained by the use of such a fall as that of Niagara, or the employment of waste coal at the pit's mouth."

CHAPTER III

PIONEER DAYS IN ELECTRIC LIGHT AND TRACTION

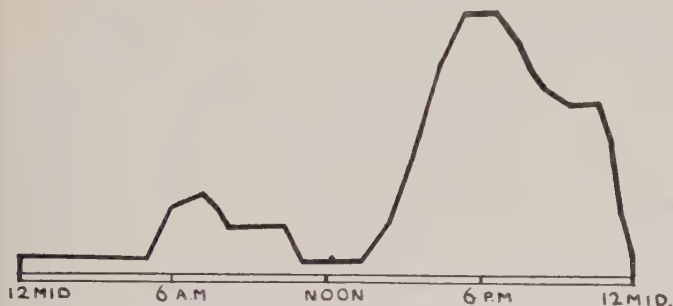
AS a business proposition, the supply of electric light had serious drawbacks. In most cases artificial light is wanted for only a few hours out of the twenty-four. On the other hand, the supply has to be available at all hours. Gas undertakings do not feel these conditions so severely, because they store the gas in large holders and are able to draw upon these reservoirs as required. Electrical engineers, it is true, have a parallel reservoir in the storage battery, but although they have made considerable use of it they have found it much more expensive than the gas-holder proved to the gas engineer.

The simple electric light station, in fact, has to instal plant which is able to meet the largest demand likely to be imposed upon it. If we draw a curve representing the course of the daily demand upon such a station we get a long, low line rising to a peak in the evening and falling away again almost to nothing. During summer the peak is only a modest hill, as winter approaches it rises, and during Christmas week it becomes a veritable alp. All the low parts of the curve mean waste. Coal is being burned to keep up steam ; the engines are running light ; and the staff is in attendance ; but there is little business afoot, little revenue being earned. For every hour of the day, moreover, the buildings and plant are costing a certain amount in interest, depreciation, and other " standing charges." Clearly, therefore, the fat hours must pay, and pay heavily, for the lean hours, and the price charged for electricity must be much greater than if use were made of current more steadily over a longer period each day.

Ever since these elementary facts were realised, electrical

engineers have been trying to fill up the valleys in the load curve. The ideal they are aiming at is a straight line—a plateau at the height of the full output of the station. They are still a long way from this ideal straight line, which may stand as a kind of mathematical symbol for the all-electric age, but they are gradually getting nearer and nearer to it. Their approach is by way of adding new demands which are heaviest in daylight hours or after midnight, when there is little demand for light. From electric light they pass to electric supply for a variety of purposes.

The first important new demand to be added was for operating tramways. Tramways start work in the early morning,



The curve represents the daily "lighting load" in a provincial town. The small peak between 6 a.m. and noon is due to the charging of storage batteries, which act as a stand-by at the power station. The real demand comes on suddenly in the afternoon, rising to its summit after 6 o'clock, and falling away towards midnight, when nearly all lights are turned out. Thus between midnight and 5 a.m. of the following day there is practically no demand and the machinery is almost idle.

et very active during the business rush hour, ease off until the afternoon (with perhaps a livelier time before and after the luncheon hour), become very busy when offices and factories close, and are slack again until the theatre crowds come and go, leaving only a small spasmodic demand until the last car goes to bed in the depot. It will be noted that although the tramway load rises and falls, it does not clash with the lighting load. Before the evening rush for the tramcars begin, the lights are out in factories, offices, and other business establishments. The arrival of the homecomers means the switching on of more electric lamps, but by that time the tramway rush is over.

Similarly, the more people there are on the way to places of amusement by tramcar, the fewer there are at home using electric light.

In a large city the dovetailing is not quite so neat and simple as we have described, but on the whole the adding of the tramway business to the electric light business greatly improves the appearance of the load curve. The fact that tramways need a wholesale supply of current, while not calling for it all on the top of the lighting load, makes it possible to give the supply at a low price and a good profit.

The all-round improvement in the business, moreover, enables the undertaking to reduce the price charged for lighting.

Electric tramways were thus a step towards that cheapening of electricity which opens the way to the universal adoption of electricity. Other "day-loads," such as that afforded by the driving of factories, were added with still better results, which will be discussed in later chapters. For the moment we must review the early days of electric tramways.

The first electric tramway was a railway. This bull may be permitted because, as we have seen, the pioneer undertaking was in Ireland, and also because the Portrush line was really more like a tramway than a railway in the volume and character of its traffic. Most of the other examples of electric traction between 1883 and 1896 were of much the same character—short lines laid on private tracks. Electric traction was in those days regarded as a danger to the public, and the "overhead wires" with which we are now so familiar on tramway routes were anathema. Years of pioneering work had to be undertaken before public prejudice could be broken down to the point of allowing tramcars to be propelled by electricity.

Public prejudice was not, however, the only reason why a new mode of transport which had been tried out in 1883 did not begin to come into general use until more than a dozen years later. The story of electric traction brings us up against the same depressing element as that of electric lighting—the element of legislation. Most of the old horse tramways had been built under the Tramways Act, 1870, which was the model used for the ill-fated Electric Lighting Act, 1882.

'twenty-one years' life was the tenure allowed for horse tramways, ending in expropriation at scrap-iron value. When electric traction came upon the scene as a business proposition, horse tramways were within sight of their end. No more money was being spent upon them than would suffice to keep the cars intact ; and the track was becoming a positive danger to traffic. To spend more would have been throwing good money away.

In these circumstances it was impossible to think about electrifying horse tramways until a renewal of the tenure had been obtained. The obstacles to this course were numerous and formidable ; many precious years were wasted before they were overcome. Here again we observe that not the incapacity of our electrical engineers, nor the lack of enterprise among our business men, was responsible for the delay in establishing a new use of electricity. We must look once more to Whitehall for the cause of backwardness ; and we must note, for future guidance, the unhappy result of placing shackles upon the spirit of engineering progress.

As soon, however, as a good start had been made, the conversion of horse tramways went ahead pretty quickly. Electric tramways became a fashion which every city and large town felt compelled to adopt. The enthusiasm with which corporations and companies plunged into this field of development may seem a little too fervent to-day, when there are hints of electric tramways being obsolete. Nevertheless, the arguments which were so impelling in 1896 are still sound ; and as they form part of the case for other uses of electricity it will be useful to state them briefly.

The dynamo, or electric generator, is a reversible engine. It can drive as well as be driven. It can either convert mechanical power into electrical, or convert electrical into mechanical power. The electric motor, therefore, is similar to a dynamo and enables any kind of machine to be driven by electric power. In practice many differences in design are introduced to make both the dynamo and the motor more suitable for their respective functions, but in principle they are twins.

The electric motor has one peculiarity which sets it apart from all other means of propelling vehicles. Everybody must

have noticed the difficulty which horses have in starting a heavy load ; they need to put forth their full strength until the vehicle begins to move, and thereafter they settle down to an easy trot. Precisely the same thing is to be observed in the starting of trains and motor-cars—the greatest effort is needed at the moment of starting. Neither the horse nor the steam or petrol engine is suited to these conditions. In getting a heavy load under way, especially on an up grade, a horse has to strain every muscle ; the power exerted by a steam engine is limited ; and in the case of a petrol engine it is necessary to start on a low gear and change the gear after the vehicle is moving. An electric motor, on the other hand, exerts a great turning power at the instant current is switched on ; and it has a large reservoir of power (at the generating station) to draw upon. It is perfectly adapted, therefore, to the efficient driving of a vehicle, giving a quick start and a very low consumption of power while the vehicle is running.

Another source of economy on an electric tramway is that the cars do not carry a source of power with them. Horses have to haul themselves along as well as the vehicle behind them ; a steam-driven car is loaded with boiler, furnace, engine, fuel, and water ; and a petrol car has its engine and gears. On an electric tramcar there are simply a motor and a controller which regulates the supply of electrical energy to the motor. All the power-producing plant is concentrated at the central electric station, so that the cars themselves “ travel light.”

The advantage of this arrangement does not stop at relieving the car of dead weight. As a general rule, the larger the plant used for producing power the more economically it performs its work. So far as generating electricity is concerned, it is cheaper to use a single engine of 1000 horse-power than to have engines of 10 horse-power each on one hundred cars. In first cost a single installation is cheaper than the equivalent number of small plants ; and in a large stationary power house it is possible to introduce refinements which tend to economy and long life. Further—and this is a most important point—when power is centralised it is not necessary to provide so much horse-power as when each vehicle carries its own engine.

At first sight this may seem rather puzzling, but the explanation is simple enough. An engine driving a car must be powerful enough to meet the heaviest demand—that of starting the car with a full load of passengers on the steepest hill. If we have one hundred cars so equipped, the total propelling power required is found by simply multiplying this maximum demand by one hundred. On any transport system, however, it never happens that all the cars make this maximum demand at the same moment. While some are running up hill and using a good deal of power, others are running down hill and taking no power at all; while some are starting, others are stopping or at rest. Thus the actual total demand made by the hundred cars at any instant is always less, and considerably less, than one hundred times the highest possible demand of any car. And as it is the actual total demand which the central power station has to meet, the plant in the station need not be nearly so large or so costly as the 1000 horse-power installation just mentioned.

The saving thus effected is enhanced by another virtue of the electric motor—its capacity for taking heavy overloads. A motor which normally gives 10 horse-power can give 20 horse-power for a few minutes without suffering any damage. Smaller overloads can be carried for longer periods. Among other means of propulsion the steam engine comes nearest to the electric motor in its ability to meet a sudden overstrain, but it is a long way behind. The petrol engine, which is the most direct rival of the electric motor for street traffic, is rather like the trade unionist in its reluctance to do more under any conditions than it is rated to do. Full advantage of the overload capacity of the electric motor is taken in equipping tramcars. The size of the motors is determined by the normal demand upon them, and the abnormal demands, which are usually spasmodic, are left to the overload capacity. Thus the size, cost, and power consumption of the motors are reduced to the lowest figure.

Bound up with this question of economy in transport is the use of rails. The pull required to haul a vehicle (fitted with solid rubber tyres) along an ordinary macadam road is about ten times what is necessary for a vehicle with steel wheels

running on steel rails. Because of this difference horse omnibuses used to seat about half the number of passengers carried by a horse tramcar ; and to-day the largest motor omnibuses have about half the carrying capacity of electric tramcars. In this connection it is interesting to note that Lord Montagu, a leading motor enthusiast, has recommended the laying of special plateways of steel or concrete for ordinary commercial vehicles. This is a reversion to the primitive tramway, in which a broad track of timber or iron was laid for the wheels of trucks.

All these arguments lead to one conclusion. For the conveyance of large numbers of passengers along roads the most economical system is the electric tramway, with its centralised power and its large cars which are " quick off the mark " and capable of high speed with a minimum expenditure of power. Certain conditions are, of course, necessary for the full enjoyment of the economy of electric traction on roads. The roads themselves must be fairly wide so that the tracks may be free from chronic obstruction ; the volume of traffic must be large and well maintained ; and the system must be laid out so that the cars can be loaded up and dispatched quickly at the termini. These conditions are not always present in our towns. They—with the exception of the volume of traffic—are notoriously absent in the central portions of London, about which the controversy of motor omnibus v. tramcar rages most fiercely. But in cities such as Glasgow, where the configuration of the streets and the movements of the population are favourable, electric tramways show an unrivalled capacity for dealing with heavy street traffic at a low cost.

In a later chapter we shall discover that the electric tramway is far from being the only contribution which electricity makes to the road traffic problem. At this point, however, it is useful to emphasise the fact that the problem is in any case much too complex for a single solution. Much of the argument on road traffic is conducted as if the proper destiny of one or other mode of transport were to sweep all the others away. The real task of the traffic engineer is to discover the service or services best suited to a particular locality ; and in performing this task he has to consider the size and distribution and character of the

population, the topography of the district, the nature of the road surface, the cost of various forms of energy, the local labour conditions, and a hundred other factors, any one of which may make the difference between success and failure. We are likely, therefore, to see various forms of road transport supplementing each other. So far as electricity is concerned, it promises to play a leading part in dealing with almost every class of demand.

Striking proof of the complexity of the transport problem is afforded by the comparative history of electric tramways and electric railways. As we have seen, electric railways were first in the field and prepared the way for the tramways. The electric tramway boom was well-nigh over before a serious development began to take place in electric railways ; and to-day, when tramway extension has practically ceased, ambitious schemes are on foot for the electrification not only of suburban railways, but also of main lines for both passenger and goods traffic. To-day, also, there is a marked revival in long distance road traffic, which introduces many new problems for the engineer to solve. To-morrow, with the provision of cheap electric power over wide areas, we may witness a revival of the electric tramway in the form of the electric light railway.

For the moment, however, we are concerned with the reasons which determine the change from steam to electric traction on railways. In large measure they are the same as those which led to the conversion of horse tramways, but there are certain conditions of railway service which accentuate the benefits of electric propulsion.

Electric traction was first used on railways for which steam traction was either objectionable or impossible. The Liverpool Overhead Railway, which was opened in 1893, runs on girder track over the streets ; and under such conditions the use of steam locomotives would have involved serious drawbacks. The City and South London (1890), which was the pioneer tube railway, was constructed at so deep a level that ventilating shafts for the escape of steam and smoke were impossible. These cases of necessity were very useful in proving what electricity could accomplish on railways and in

breaking down the conservatism of railway companies and the public.

When we come to the first British railway which was converted from steam to electric traction, we find that both physical and financial troubles provided the incentive towards the change. The railway under the Mersey has heavy gradients at each side of the river ; it runs through a very wet tunnel, which needs continual pumping on a large scale ; and with the fumes from steam locomotives the ventilation of the tunnel proved a costly and difficult business. Electrical working provided an efficient cure for all these disabilities.

A more familiar example, however, was the Metropolitan District Railway in London. The atmosphere of that line in the old days was a scandal, although some optimists used to declare that the sulphurous fumes were an infallible cure for asthma. The financial conditions were not more cheerful, since the railway had never managed to pay a dividend on its ordinary shares. The only chance of improvement lay in making the railway more attractive, increasing the volume of traffic, and reducing the ratio of working costs to receipts. And the only way in which these things could be done was by means of electricity.

One of the features of electric traction is, as we have seen, its rapid acceleration. Where stations are close together slow acceleration is a very serious drawback. On the old " District " the trains had hardly time to get up speed before the brakes had to be put on to bring the train to a stop at the next station. The average speed, therefore, was very low. The frequency of the service was also low, because of the length of time which each train took to clear a section and allow the next train to advance. With a slow and infrequent service traffic was discouraged, and the public found it more convenient to make its point-to-point journeys on foot or by horse omnibus.

With electric traction the time between station stops was shortened, because the trains picked up speed much more quickly. The higher frequency of service was assisted by the introduction of automatic signalling, which prevented the loss of time and the risk of mistake due to the old system of operation by men in signal boxes. Each train as it goes along does its

own signalling by operating levers placed close to the rails, and the working of the apparatus is safeguarded by a simple arrangement which, when a train enters a section which is not cleared, cuts off the current and puts on the brakes.

The first effect of electric traction is, therefore, that it raises the traffic capacity of a railway. This is a very important benefit. Most of the expense of constructing a railway is due to the permanent way, with its embankments and cuttings,



An electric train on London's latest electrified suburban railway—the extension of the Central London Railway to Ealing. Current is supplied to the trains by the third rail between the running rails.

and to the stations with their platforms, sidings, and buildings. The prospect of being able to earn a dividend upon the money sunk in these works depends upon carrying a certain volume of traffic; and that condition often depends, in turn, upon running a speedier and more frequent service than is possible with steam traction. If we consider a particular train of carriages and compare the costs of hauling it from Ealing to West Ham by steam and by electricity, there may be little economy in the electric way. It is not the saving in expense which has induced the railway manager to turn to electric

traction ; it is the possibility of earning more revenue by doing more business.

The greater carrying power afforded by electric traction is also the salvation of a suburban line which suffers from congestion of traffic at the rush hours. One has only to watch the proceedings at a busy London terminus to realise how difficult it is to maintain a rapid flow of steam trains. After each train has arrived and discharged its passengers, a locomotive has to be coupled to the rear end in order to haul it out again and make way for another train. However this operation is done, it occupies many minutes of precious time. The frequency of the incoming service is, in fact, limited by the period occupied in shunting.

If electric trains were hauled by locomotives they would, of course, suffer from the same disability. But in the modern suburban electric train the front and rear cars, and frequently the centre car as well, are equipped with motors and with a driver's cabin. Therefore, on arrival at the terminus, all that the driver has to do is to walk through the train or along the platform and take up his station on the rear car, which then becomes the leading car. He can do this while the passengers are alighting, so that not a moment need be lost in clearing the line for the next incoming train.

This method of splitting up the driving equipment is known as the "multiple unit" system, and it is useful for other reasons than the rapid clearance of the bottle-neck at a terminus. On the ordinary suburban railway the traffic is very thin during the greater part of the day. Some sort of service must, however, be maintained, and thus we get the familiar spectacle (on steam railways) of long trains, at infrequent intervals, carrying only a few passengers. This "dead mileage" is a source of heavy waste in coal and in wear and tear of the rolling stock and permanent way. Yet with steam traction there is no help for it, because the expense of breaking up the trains and running three-car or four-car trains during the slack hours would not be worth while. Steam locomotives, which must be powerful enough to haul crowded trains at top speed, work very inefficiently at light loads.

With an electric train on the multiple unit system, on the



GOODS TRAIN ON THE NEWPORT-SHILDON SECTION OF THE GREAT EASTERN RAILWAY.

Hauled by electric locomotive. Overhead wires are used to convey the current, which is collected by sliding bows carried by the locomotive.

other hand, it is a perfectly simple matter to split up a full-sized train, giving a three-car train with one motor-car and two trailers, or a five-car train with two motor-cars and three trailers, or indeed any number of cars which will suit the variations in traffic. Each train, no matter what its size may be, takes only that amount of power which is required to propel it at the desired speed. Thanks to these advantages a frequent service can be maintained on an economical basis throughout the day. The frequency of the service, in turn, encourages people to travel on the line, and so creates traffic for which no steam line is able to cater.

These advantages are worthy of description in some detail, because they illustrate the true value of electricity not only on railways, but in many other directions. *Better service* is what electricity offers, rather than a cheaper way of doing some particular thing. Direct economies nearly always accompany the use of electricity, but its indirect economies are often much more important; and its convenience and flexibility lead to its adoption for many industrial and domestic purposes which would be met otherwise if cheapness were everything.

CHAPTER IV

ELECTRIC TRACTION ON ROADS

THE revival of road transport during recent years has been so remarkable that some enthusiasts have prophesied the decay of railway traffic in favour of the automobile. The broad highway is to have its revenge upon the systems which deprived it of its traditional glories.

Posterity will pass a final judgment upon this forecast. For the present there is no expectation, among the more sober authorities, that any one form of transport will swallow another. Railways, on the one hand, are destined to be electrified ; and, on the other hand, roads are certain to witness the development of a variety of forms of mechanical propulsion. If there be any one type of haulage which is likely to diminish steadily in importance it is horse traffic. But even then, so great is the variety of human needs and circumstances, it will be a long day before the horse ceases to be a factor in the transport problem, especially in country districts.

Among all the conflicting opinions which are expressed about the future of road transport there is a general conviction that electricity will have little to do with it. The " motor " which is to conquer the roads is not, so the argument runs, the electric motor. Suburban railways may be converted ; main line railways, both for passengers and goods, may likewise pass over to electric traction ; our industries, including agriculture, may be completely electrified ; and our homes may be lighted, heated, and operated electrically. But in the all-electric age there is apparently to be one conspicuous exception.

It is not difficult to see how this conviction has arisen. The essential thing demanded of a road vehicle is that it should be

able to run hither and thither without restriction. Electric power is distributed by means of wires carried overhead on poles or laid underground in conduits, and any vehicle which uses that power must maintain contact with these wires. Until, therefore, every road is provided with an electric power supply, vehicles which are to enjoy the freedom of the highway must carry an independent source of power in the form of a steam or internal combustion engine.

The electrical engineer does not dispute this argument, but he does not agree that it covers the whole ground to the exclusion of electricity. Without straining probabilities, he looks forward to the time when every type of road vehicle will be electrically driven.

In the first place we may consider the possibility of developing an electric road service which takes power from a wire. On an electric tramway system each car collects current from a trolley wire by making continuous contact through a wheel at the end of the trolley pole. The current passes down the pole, through the controller which the driver operates, through the motors driving the car, and thence by the rails which form the return circuit to the generating station. If we take a car similarly equipped, but running on ordinary wheels, we can propel it electrically by providing it with a second trolley pole making contact with a second trolley wire forming a return circuit. The current then travels along one trolley wire from the generating station, down the first trolley pole, through the controller, through the driving motor, up the second trolley pole, and thence by the second trolley wire back to the station. This is the general idea of the electric trolley omnibus or auto-trolley, which is able to manœuvre on a road with almost the same freedom as an automobile.

Trolley omnibus systems are at work in Leeds, Bradford, and other towns as "feeders" to tramway systems, and on roads where the traffic is not heavy enough to justify the expense of laying rails. For the most ambitious example, however, we must go to Shanghai, where the trolley omnibus is used as the primary mode of transport. The facility with which the vehicles thread their way along streets crowded with rickshaws and foot passengers is remarkable; and under the

conditions prevailing in that city the results are so good that a wide extension of the system has been undertaken.

When the trolley omnibus was a novelty it roused great enthusiasm. One electrical engineer had a vision of roadways



DOUBLE-DECKED ELECTRIC TROLLEY OMNIBUS

Put into service by the Bradford Corporation. This vehicle can manœuvre freely from side, to side and forms a compromise between the electric tramcar and the motor omnibus.

provided with trolley wires from which all types of vehicle—transport lorries, farmers' wagons, and private cars, as well as regular passenger vehicles—would draw their power. This vision was to some extent a revival of the notions entertained

by the projectors of the first railways. The "iron horse" was expected to haul carriages belonging to all and sundry. Very soon, however, it was found that this arrangement would not work, and the railway companies were obliged to provide complete traffic facilities with their own vehicles, except in the special case of coal wagons. In the case of the trolley omnibus, likewise, there is no prospect of ordinary vehicles being equipped with electric motors and trolley poles, even if trolley wire power were made available over a wide area. Something much more modest is allotted to the auto-trolley. Where electric current is cheap and the conditions are otherwise favourable, it will be found on the outskirts of tramway systems as an electrical alternative to motor omnibuses.

One drawback to the auto-trolley is that the route cannot be readily changed if it proves unprofitable. The same drawback applies to the tramway, but there it is atoned for by the economy of running vehicles with steel wheels on steel rails. So great is the practical advantage of having a vehicle independent and free-running that the advantage of the steel-on-steel principle is cheerfully forgone except in cases where heavy traffic along fixed routes can be relied upon. Chiefly for this reason there has been, during recent years, a rapid development in motor omnibus traffic, both in connection with tramways and independently.

There are two types of automobile propelled by electricity. One is a direct evolution from the petrol vehicle; the other is wholly electric.

The first petrol vehicles had only one electrical thing about them—the magneto or sparking plug which effected the explosion of the mixture in the cylinder. Many modern cars, however, are fitted with electric starters, electric light, electric horns, and even electric heaters. They have, in fact, become so largely electrical that one step further would make them wholly electrical. That step is the crucial one of using electric gear between the engine and the driving wheels. This can be done by using the engine to drive a dynamo and transmitting the current to motors attached to the back axle.

At first sight it seems absurd to convert mechanical energy into electrical energy merely in order to convert it back again

to mechanical energy. The direct mechanical drive from the engine to the axle appears to be much more efficient. But in practice the electrical system has many advantages. Petrol engines are essentially high-speed machines. They run most economically at something like five hundred revolutions per minute, yet they are called upon to drive the car at anything from a crawl up to a speed which represents something like forty revolutions of the driving axle. To effect this speed reduction and to give the requisite speed variation, a complicated speed-reduction gear is used, and the engine is on occasion throttled down to a lower speed than the normal and efficient rate.

The change-speed gear on a modern car is a wonderful contrivance for making the best of a bad case. A French inventor who devised one of the early types immortalised it in the phrase, "C'est brutale, mais ça marche." How brutal it is can be realised by anyone who stands in a busy city street and listens to the grinding and groaning of the gears in the petrol-driven vehicles which form the major part of the traffic. Most of the distracting noise of motor traffic is due to the gears ; and most of the heavy wear and tear on the car is accounted for by the jarring which takes place on a change of speed. The blunt fact of the matter is that the transmission gear on the petrol car is, from the engineering standpoint, a makeshift or compromise between two irreconcilable elements--the high-speed prime mover and the axle whose speed varies from nothing to a comparatively low rate of rotation.

When we turn to the petrol-electric car we find a very much happier state of things. The engine is coupled direct to a dynamo, and whether it is running light or propelling a loaded car up a steep hill it maintains a high and therefore an efficient speed. The current it produces is led through a controller to motors which drive the wheels by means of a chain. As on a tramway car, these motors take current according to the needs of the moment, giving a powerful starting effect and using less energy as the car gains speed. Starting, accelerating, reducing speed, and stopping are all performed smoothly and sweetly, without any sudden destructive strains on the

mechanism. From the point of view of the comfort of passengers the petrol-electric system is immensely superior to the plain petrol system with mechanical gear; and, in spite of the double conversion of energy, it is very economical, while it gives a longer life to the equipment and the tyres.

Large numbers of petrol-electric vehicles have been built for commercial work, and many are in service as omnibuses. They are gaining steadily in popularity, and their progress would probably be more rapid if motor-car designers were not wedded to the methods with which they are most familiar. Mechanical transmission on motor-cars seems to have reached the limit of its possibilities, but there is still room for progress in the efficiency and flexibility of electric systems, so that in time we may see petrol-electric cars driven by much smaller engines than are at present considered necessary. Even as things are, the petrol-electric vehicle is at least a close rival of the ordinary petrol car, and there is nothing in the situation to oppose the ultimate conquest of road traction by electricity. Little has yet been done in applying electric transmission on private cars or other light vehicles, but there is one promising development which uses electrical gear at the lower speeds and a direct mechanical drive at top speed. The advantage of this arrangement is that the loss due to the double conversion is cut out when the car is running along the open road.

At the other end of the scale of magnitude in road transport the petrol-electric combination provides the only satisfactory solution of a difficult problem. Many economies and conveniences become possible when a road locomotive is used to haul several trucks, thus forming a "road train." For various reasons the locomotives of road trains are generally driven by steam, but whatever the motive power may be there are serious disadvantages where all the driving mechanism is concentrated on the locomotive. In order to get sufficient grip on the road surface to haul two or three trucks loaded with several tons each, the locomotive must be made very heavy. Every extra hundredweight put into it to increase its adhesion involves more wear on the road and more power in moving the machine. These two factors together mean that the speed of the train must be kept very low in order to save

fuel and to prevent rapid destruction of the road. No wonder, therefore, that the law looks with a cold eye upon road trains and imposes heavy restrictions on them.

All these drawbacks vanish when electric transmission is adopted. The locomotive becomes little more than an electric generating station on wheels. It supplies current not only to electric motors driving its own wheels, but to electric motors similarly arranged on all the trucks. Each truck thus becomes a "motor-car," and the driving power, instead of being concentrated on one pair of wheels, is divided over several pairs, giving a much better grip of the road with much less weight per axle. The electric generator can be driven either by a petrol engine or (as is more suitable for larger sets) by an engine using heavy oil; and the equipment is so light and compact that part of the chassis becomes available for carrying purposes, making the locomotive a tractor-truck. By a simple arrangement of the couplings each truck follows exactly in the track of the leading car, so that steering presents no difficulty. Road trains of this type are no more severe than individual cars on road surfaces. In the conveyance of heavy loads from such places as quarries or mines, and in military transport, they present so many advantages that they are sure to be largely developed in the near future.

At this point we may interpolate a brief reference to the electric ship, as it illustrates the same principle as the petrol-electric car. When the steam turbine was first introduced on vessels, great difficulty was found in designing a propeller which would work efficiently at the very high speeds attained by the steam turbine. In order to overcome—or rather to avoid—this difficulty, it was proposed that the turbine should be coupled direct to a high-speed electric generator which should supply current, through control gear, to slow-speed motors attached to a short propeller shaft. The name of Captain William P. Durtnall is most intimately associated with the genesis and growth of this system of ship propulsion, as well as with various combinations of prime movers and electric driving on automobiles and locomotives. He urged, in the face of much opposition from conservative engineers, that electric propulsion would give higher efficiency, ideal control

for manœuvring and reversing, very low fuel consumption at cruising speeds, freedom from propeller "racing," and many other advantages. All his claims have been substantiated by the American Navy, which was the first to put the designs proposed by Captain Durtnall into practice on a large scale, all its recent battleships and battle-cruisers being electrically propelled. The system has since been extended to merchant ships. One of its incidental benefits is that it enables the ship to be controlled by simple electrical switch-gear placed on the bridge.

Another invention of Captain Durtnall's may be mentioned to indicate that some day our aeroplanes may be electrically driven. He suggests that a flying machine could be constructed with a series of wings, each worked by an electric motor so that its movement would imitate closely the action of a bird's wing. Power for these motors would be supplied from a single electric generator on the machine. With this equipment the machine would be able to rise almost vertically and to "hover" in bird-like fashion as well as fly at a high speed. So far this ambitious scheme has not been tried, but in view of the apparently insurmountable limitations of the aeroplane it should be made the subject of experiment and may yet complete the electrical conquest of the transport world.

The second type of electric vehicle referred to is the storage battery car. Here the source of power is an accumulator similar, in principle, to that already described in connection with electric lighting. The accumulator is charged from the public electric mains or from an independent electric generating set, and it is carried on the car, supplying power to electric motors which drive the wheels through simple speed-reducing gear of the chain, worm, or pinion type. After the vehicle has run a certain number of miles the battery has to be recharged.

Electric battery traction was tried long before the petrol engine made its appearance ; and its early history was a record of high hopes and deep disappointments. In theory, battery traction was, as recent experience has proved, quite sound ; but in practice it was a failure because the batteries were not robust. When an electric battery is charged and discharged,



Small electric battery trucks are largely used for hauling loads in railway stations, docks, and factories. This photograph was taken in Euston Station, London, during the war, when the trucks were driven by women.

certain chemical changes take place in the material of which the plates are built up ; and if the battery is subjected to jolting and vibration—as it must be on a moving vehicle—the material is apt to disintegrate and bring the battery to an untimely end. The batteries of to-day are cleverly designed to prevent this rapid disintegration, but the batteries used on vehicles in the 'eighties were very fragile. They were also very heavy in relation to the power they supplied. The vehicles themselves were badly designed and constructed ; and the finance of most of the pioneer battery transport schemes was in harmony with these unpromising conditions. The net result was that early electric vehicles gained an unhappy reputation.

The only electric vehicles which survived the era of disappointment were electric broughams for city use. They were practically noiseless ; they were clean ; and they ran with a smoothness which no other kind of vehicle could approach. When Hyde Park was closed during certain hours of the day to motor-cars, on account of their noise and fumes, an exception was made of battery vehicles, which were distinguished by a red star on the dashboard. They were then, and are still, the motor-cars *de luxe* ; but even as an investment they had their attractions. One electric brougham in London has been on the road for over eighteen years. The batteries have, of course, been renewed several times during that period, and the motors and accessories have undergone repair from time to time, but the chassis and body are substantially as good as they were nearly twenty years ago. No other mechanically propelled vehicle could show a similar record.

Here we may diverge for a moment to mention another form of battery propulsion which has been steadily maintained from the earliest days. The electric launch is the ideal river craft—silent, clean, odourless, moderate in speed, under perfect control. Its equipment consists of a battery, a controller, and a motor attached to the propeller shaft. As most river cruises consist of comparatively short journeys which end at the point from which they began, the limited range on a single charge of the battery is not a serious drawback. Longer trips have been made possible on the Thames by establishing several charging stations.

These two cases—the electric brougham and the electric launch—have been dwelt upon because they show that electric battery traction is intrinsically right. Given a battery which would stand up to its work for a certain number of years, and would yield greater power, weight for weight, than the early types, there was nothing to prevent the rapid multiplication of electric vehicles for town transport. One of the great electrical inventors who never lost faith in battery traction was T. A. Edison. He did, however, share the general opinion that the battery using lead plates in sulphuric acid was unsatisfactory for traction purposes ; and when he set to work on the problem he tried all sorts of other combinations of metals and chemicals in order to get a better result. Eventually, by a process akin to the survival of the fittest, he chose iron and nickel in an alkaline solution, and he constructed a battery of great mechanical strength, high efficiency, and long life. The American newspapers announced his success a hundred times before it was achieved, but eventually the Edison battery emerged from its prolonged tests as a sound commercial article whose performances could be fully guaranteed.

This was the signal for a revival of interest in battery traction. Shortly afterwards, by a familiar kind of reaction, the makers of lead batteries introduced a new form of plate which was very much more robust than the original form. As the rivals stand at present, there is very little to choose between them on a final balance. Both are giving satisfactory service, and both are sold under guarantees which ensure a definite length of service before renewal becomes necessary.

When the electric vehicle appeared for, as it were, a second time on earth, its progress was greatly assisted by the formation of the Electric Vehicle Committee—a body of electrical engineers, electric vehicle makers, transport experts, and public officials formed to promote the use of battery traction. The Committee acted as a missionary and made many converts ; but it did much more. It encouraged the setting up of charging stations ; it devoted its attention to such technical matters as standardisation of vehicle parts ; and, above all, it directed the progress of this new mode of transport into the

most appropriate channels. In dealing with any type of vehicle it is as important to know what it will *not* do as what it will do. For example, a petrol or petrol-electric vehicle is not suited to services which require low speeds and frequent stops, although it proves very economical where high speeds and long runs on open roads are obtainable. The electric battery vehicle, on the other hand, is not adapted for express transport over long distances, while it is admirably suited to work which involves moderate speeds and frequent stops with a limited daily mileage.

Here we have another and very striking example of the complexity of the transport problem. Critics of the electric vehicle used to make fun of its "steady progress"; they saw, in its relatively low speed, its limited range of movement on a single charge, and the necessity of spending many hours each day in recharging batteries, serious disadvantages to the adoption of battery traction. What they failed to realise was that there are many cases where relatively low speed is necessary or advantageous, and where the other drawbacks are negligible. This will become clear when we consider one or two typical uses for the electric vehicle.

The municipal dust cart, which collects street sweepings or dustbin refuse, has to be stopped every few yards in its progress along a road. At no time is its speed much above a walking pace, whether the vehicle is hauled by horses or driven by steam or petrol. For this work, therefore, what is desired is a wagon of large capacity and moderate speed, capable of being readily started and stopped, and absorbing no energy when at rest. All these conditions are fulfilled by the electric vehicle, and the electric vehicle alone. Refuse collection, again, is work which is carried out within a narrow compass, each vehicle traversing a certain group of streets and proceeding, when filled, to the dust destructor or the refuse dump. Finally, the work of collection is done once a day, so that there is an ample period of rest during which the batteries can be charged.

Here the limitations of battery traction do not matter in the least, while its advantages are a source of economy. In Sheffield, Birmingham, Glasgow, and other cities large and

increasing fleets of electric refuse-disposal wagons are doing this essential service to the public health more cheaply and expeditiously than it could be done by horses or any form of mechanical haulage.

Another typical case is the distribution of goods from a large city store. To a large extent the goods are delivered within a few miles of the store ; that is to say, the range of the necessary transport is limited. Each vehicle goes out loaded with dozens of packages for various destinations ; and each package involves a stop. The maximum speed of all motor vehicles in city streets is limited to a moderate figure and in any case is restricted by the miscellaneous traffic by which the thoroughfares are congested. All these conditions favour a vehicle which, although it does not enjoy a high maximum speed, maintains a good average speed by virtue of the rapidity with which it stops and starts, and the ease with which it can be manœuvred at rapidly changing speed in and out the other traffic. It is a proven fact that a petrol vehicle and an electric vehicle, starting at the same time from one extreme of London and passing through the central area, will reach the other extreme simultaneously. This means, in effect, that city deliveries can be completed as quickly by electric vehicles as by petrol vehicles with a higher maximum speed. Compared with horse transport, battery traction is, of course, more speedy, and it has the further advantage that the daily mileage which can be covered by an electric vehicle is much greater than can be attained with horses.

Another feature of this delivery work is that all the vehicles return to the central depot at the close of the working day, leaving the entire night free for the process of charging. On occasions when the roads are exceptionally bad (as, for example, if heavy snow has fallen) or when extra mileage is required, the vehicles can be given a short "boosting" charge, as it is called, during the dinner hour. Not one of the limitations of the electric vehicle, therefore, has any weight in this service. On the other hand, battery traction has many positive advantages. The control of an electric vehicle is so easy that a short period of training suffices for anyone who has experience of driving in crowded streets. Skilled mechanic-drivers are not

needed. Moreover, the electric vehicle has gained the highest reputation for reliability. Thanks to the simplicity and robustness of its electrical gear, it keeps the road for more days in the year than any other vehicle, and the item of running repairs is negligible. So important is this factor of reliability that one large London firm which distributes perishable food-stuffs by electric vehicles within a radius of twelve miles would prefer them to petrol vehicles even though the latter were more economical—which, as a matter of fact, they are not.

Many other illustrations could be given of the economy and efficiency of battery traction for what may be described as point-to-point city traffic within a circle of a few miles from a central depot. This is a type of traffic which is not much thought about when road transport is being discussed. "Road Transport" for most people means the conveyance of goods from one town to another over long stretches of open road. There is, however, an enormous volume of traffic of a humbler order. Every load of goods brought to a railway terminus has to be distributed by road vehicles to warehouses, shops, houses, or other scattered destinations. Every load dispatched from a terminus has likewise to be collected by road vehicles from a variety of places. Every large shop is engaged in collecting and delivering within a restricted area; every market, every warehouse, every brewery, every coal depot, calls for a similar service. Some of this local transport is carried out by steam or petrol vehicles, but most of it is still done by horses, on account of the unsuitability of mechanical haulage to point-to-point transport at low speeds. In time all of it will be taken by light or heavy electric vehicles. The change has already begun to take place, and it will proceed with increasing rapidity as the proof of the superiority of battery traction in this field is more widely appreciated.

Two results of great importance to the public will follow the change. Traffic congestion presents a very serious problem in London and many other cities; and it is the source of so much delay that elaborate schemes of road widening have been proposed and, in several instances, carried out. Every now and again civil engineers and amateur reformers amuse them-



ONE OF THE FLEET OF ELECTRIC LORRIES USED BY THE CLEANSING DEPARTMENT OF BIRMINGHAM
FOR THE COLLECTION OF HOUSE REFUSE

This vehicle is fitted with electrically operated tipping gear.

selves with visions of two-storied thoroughfares or expensive cross-overs at crowded junctions.

It may be noted, however, that the traffic capacity of any thoroughfare does not depend solely on its breadth. It depends also on the average speed of the vehicles through it, and the average space occupied by each vehicle per ton of load carried. The rate of flow of traffic along a street is determined to a great extent by the speed of the slowest traffic, and so long as horsed vehicles are common so long will we have the familiar spectacle of "fast" traffic delayed or blocked by vehicles hauled at a walking pace or slow trot. These horsed vehicles survive because they cannot be replaced efficiently by petrol or steam vehicles; they can, however, give way with advantage to electric vehicles; and when this change takes place the average speed of the slowest traffic will be doubled and the whole stream of traffic will flow much more swiftly than it does to-day.

The density of the traffic will also, in one sense, be increased. An electric vehicle capable of carrying one ton takes up about half the road space of a horse-drawn wagon with the same capacity. The value of this saving in space is not generally realised, but it is really very high. It means that by using battery instead of horse traction the amount of traffic which can be passed along a road may be doubled, even though the average speed of the traffic is not increased. Add the value of the higher speed of electric vehicles, also their more rapid acceleration and the ease and rapidity with which they can be manœuvred, and it becomes clear that the traffic capacity of a street may be trebled. Here we have at least a partial cure for "bottle-necks." To widen a bottle-neck is a most costly business. To get a larger tonnage of goods through it at a faster rate is as good as widening the road and is a measure of economy all round.

In short, battery traction does for city roads what electric traction does on tramways and railways. It enables more traffic to be carried at a lower cost per ton.

The second result referred to is an improvement in city sanitation. Horses in a city are a nuisance from the sanitary standpoint as well as from that of the transport engineer. They

litter the streets, and the stables in which they are housed form the breeding ground of flies and other insect pests. Many sanitary authorities would like to banish horses completely from crowded city areas in favour of mechanical traction; and proposals with that end in view have been put forward more than once. Road surveyors would not be unwilling to support the change, because the hammering action of horses' hoofs and the cutting effect of narrow iron tyres are destructive of the smooth hard surface which is desirable for motor traffic. Further, there is great difficulty in securing a surface which will provide a satisfactory foothold for horses and will yet be efficient for mechanically propelled vehicles. The whole problem would be very much simplified if motor traffic alone had to be considered.

From the standpoint of amenity, if not of sanitation, electric vehicles are much to be preferred to either steam or petrol vehicles in city streets. Smoke and fumes are inseparable from steam traction, and petrol traction involves the constant emission of exhaust gases. Both steam and petrol—but petrol in particular—are associated with a variety of noises which, in spite of all the voluntary and compulsory efforts to allay them, fill a modern, busy thoroughfare with a distracting medley of the unloveliest sounds that ever assailed the ear. Horse-drawn vehicles add their clatter, rumble and rattle. Battery vehicles, on the other hand, are practically silent; almost the only sounds they emit are the trickle of the driving chain and the faint hum of the motor. In the all-electric city neither the air nor the surface of the streets will be polluted; and those who take their walks abroad in crowded thoroughfares will be able to converse in comfort.

The electrification of the internal goods transport of London and other cities has already begun, and it is sure to proceed rapidly, at the expense—for many years to come—of the horse. In other directions the prospects are not so definite, if we take "electrification" to mean conversion to battery traction. Motor omnibuses, for example, will be petrol-electric rather than battery-electric, although electric omnibuses are in satisfactory service already in more than one town. Where the gradients are not excessive and the road surfaces are good,

electric omnibuses work very efficiently ; but for the rough-and-tumble conditions in many towns the petrol-electric system may prove to be better adapted.

There is, actually, a more promising field in the taxicab service, which is seldom considered as offering any scope for battery traction. In Detroit, Chicago, Amsterdam, Berlin, and in other cities of the United States or the Continent, electric taxicab services have been established with success. The electric cabs are preferred by the public because they are clean, noiseless, and smooth-running ; the speed is ample for city streets—running up to twenty-five miles on the level ; and the fares are very moderate. A mileage of sixty can be covered on a single charge, and no difficulty is found in organising the charging stations and the exchange of batteries so as to maintain an uninterrupted service. Other advantages are the freedom from breakdown, the low costs of maintenance and repair, and the fixed price of the power used to propel the cabs. Every kind of liquid fuel is subject to violent fluctuations in price, but it is possible to make long-term contracts for the supply of electricity to be used in charging batteries.

It is a fact, and a vitally important one, that every item in the cost of running an electric taxicab or any other battery service can be closely calculated in advance. There is no need to leave wide margins for contingencies. The precision with which the performances of the electric vehicle can be estimated is so high that, even in the early days of the battery traction revival, electric vehicle makers were able to give positive guarantees that the cost of running a specified service would not exceed a definite figure.

The features of battery traction which make the electric taxicab a promising speculation point to a revival in the popularity of private electric cars. Their main disadvantages are that they cannot—at least under present conditions—be used for touring ; after they have travelled thirty or so miles from their base they must return for a re-charge. Under favourable conditions a modern electric two-seater will cover ninety miles on a single charge, but the necessity of coming back to a charging station every night makes the electric car inconvenient for touring purposes.

On the other hand, there are many motorists who rarely use their cars for touring. They treat them as "runabouts," making occasional journeys which are usually well within the limits of battery traction. For this class of service, especially in urban areas where top speeds are not permissible, the electric vehicle has many good points. Its quietness, its cleanliness, its smooth running, and the ease with which anybody can learn to drive it, appeal with peculiar force to the owner-driver. Maintenance and repairs are on a much more modest scale than in the case of a petrol car ; and the tendency is to include a sum for these items in an over-all rate for garaging and for recharging the batteries. The benefit of this arrangement is that the user knows in advance the entire cost to which he will be put. He will not, as is so often the case with petrol car owners, be making an investment with unknown liabilities attached to it.

This phase of electric traction has not been exploited to any large extent in Great Britain, as the energies of makers have been wholly absorbed by the demand for commercial types of electric vehicles. But it is bound to come and to be expanded in several directions where mechanical traction has not yet been applied. The high measure of economy of battery vehicles at low speed opens up many possibilities. Electric invalid chairs are perhaps the most conspicuous example. Only a very small battery is needed to propel a bath chair at speeds up to five miles an hour ; and the equipment can be made so simple that any invalid who is capable of steering the vehicle can also manipulate the speed controller and the brakes. Another example is the light electrically propelled basket-chair in which visitors to American exhibitions made their tour of the grounds. Each chair held two people and was able to go at a fast walking pace.

There is a field, still quite untouched, for such simple vehicles, low in first cost and very economical in running, for shopping and visiting, and for excursions into the country *à la famille*. It is a mistake to assume that everybody demands speed in road transport ; many desire nothing better than an easy means of getting around without fatigue and without expense. For this humble purpose the low-powered battery

vehicle is ideal. The battery difficulty can be overcome by arranging an interchange service, by which exhausted batteries can be replaced by charged batteries. It is almost as simple a matter to effect this replacement as it is to obtain a supply of petrol. Battery interchange service can also be applied to private cars with a more normal turn of speed and to all types of electric vehicle between them and the electric cycle, the electric scooter, and the electric invalid chair.

When, as will eventually happen, every town with a supply of electricity will have its electric vehicle charging station, the limitations of range which at present affect battery traction will be very much modified. Already it is possible, by a judicious selection of route, to carry out a long tour by electric vehicle, the terminus of each day's run being a district where charging facilities are available. Year by year more charging stations are established; and with each addition the freedom of the electric vehicle is enlarged. Here, however, it is probable that the commercial vehicle will be in advance of the private vehicle. If we picture a chain of charging stations at convenient intervals between, say, Manchester and Birmingham, the physical possibility of regular goods transport by electric wagons between these cities becomes manifest. At the moderate speeds which are the rule with heavy loads, electric haulage should prove as economical for inter-urban haulage as it does for local work in cities. At any rate, the prospects are good enough to underline the hint that the present limitations of battery traction need not be assumed as permanent. Apart from all the hopes of a new way of storing electricity, the present system may, by careful development, provide a very wide application of the fact that transport at the speed to which the electric vehicle is adapted is the most economical and the most reliable.

We have already noted how the addition of the electric tramway load to the lighting load enabled an electric supply station to produce current more cheaply. The electric battery vehicle is a powerful aid towards the same end.

In the load curve of a supply station the lowest portion is almost invariably between eleven o'clock at night and six or seven o'clock in the morning. A certain amount of street

ighting, some illumination in hospitals, police stations, or other institutions which never sleep, and a few industrial uses at waterworks, railway stations, and exceptional factories, make up a small demand for which the wheels of the generating plant have to be kept running. But for the most part the night is a dead period.

It is during this period, however, that batteries are charged. The charging process goes on for about seven hours, so that it occupies practically the whole time between the death of one day load and the birth of another. Consequently the supply stations can afford to sell the current for charging purposes at a very low rate, much to the advantage of battery traction as well as of the supply undertaking. Low rates also apply to "boosting charges" given to vehicles during the mid-day meal hour, when other demands are small.

These conditions offer a direct encouragement for supply stations to establish charging stations and also to combine them with garage facilities. The revenue from the sale of current for charging purposes is, as it were, "found money," and it can be secured at a very small capital outlay on plant for charging purposes. Every supply station, moreover, has on its staff several men with the training required to enable them to look after the charging process with knowledge and intelligence.

In maintenance and repairs the conditions are closely similar. Electric vehicles require very little looking after, but the little must be done systematically and with skill if the vehicles are to keep the road—as they very well can do—for every working day in the year. With a staff of electricians at command, it is a simple matter for a supply station to undertake this expert supervision as well as to carry out any repairs or renewals which may become necessary. Ordinary garages are equipped for the care of petrol vehicles and rarely possess either the men or the equipment for dealing satisfactorily with electric vehicles. For these and other reasons the garaging of electric vehicles tends to fall into the hands of the supply authorities.

At a later stage, no doubt, when electric vehicles become very numerous, private firms will find it worth while to go

into this particular line of business. But for the present the field lies chiefly with the municipalities and the companies which give a supply of electricity to the public. Several of them have already gone into the business, and the Electricity Commissioners have acknowledged the necessities of the case by granting loans to local authorities for the erection of public garages for electric vehicles.

CHAPTER V

INDUSTRIAL USES OF ELECTRICITY

TRACING the history of the electrical industry is rather like attempting to describe a long series of campaigns in which many armies are involved. Each army moves, with its own equipment and purpose, over a particular range of territory and carries out evolutions which are largely independent yet affected in various ways by the progress of the other armies. In order to build up a complete picture of the war it is necessary to follow the story of each army in succession, afterwards collating the various stories on a broad scale of time and place. This process involves several journeys over the same period.

In our electrical case we have followed the advance of electric light through the pioneer stages and have brought the story of electric traction up to date in more than one direction. The link between these two lines of progress is the development of public electricity supply; and we have now to go back to the early eighties to pick up a thread which is of even greater importance in leading to an increasing cheapness and abundance of electricity.

We have already noted that the electric dynamo or generator is a reversible engine. That is to say it can, if *driven*, produce electricity, or, if supplied with electricity, it can *drive*. This elementary fact received a striking illustration at an exhibition held in Vienna in 1875. A workman accidentally connected one dynamo with another, and when the first dynamo was started it drove the other. From such a demonstration that the dynamo could work as a motor it was a simple step to driving a number of machines from a single generator. All that was needed was to fit each machine with an electric motor and to connect each motor by wires to the generator.

Thus was born the notion of the electrical transmission of power—the notion of conveying energy to a distance, not in the form of fuel which would require to be burned before its energy was released, nor mechanically by means of a revolving shaft, but by an electric current flowing along a wire which could be laid underground or carried on poles after the fashion of a telegraph wire.

Within that notion lay the germ of an industrial revolution no less important than that brought about by the invention of the steam engine. There is a story to the effect that James Watt, in offering a model of his steam engine to the King said, “I present to your Majesty that which all kings most desire—Power.” The inventors of the dynamo and motor might advance a wider, more democratic claim, since they provided the simplest means by which all His Majesty’s subjects might be furnished with power. Just as the original electric light plant, with its small steam-dynamo and its half a dozen lamps, afforded a sketch-plan for the public supply of electric light, so the first electric power installations, with a few motors driven by electricity from a single dynamo, foreshadowed the method by which power would be distributed from a central station over hundreds of square miles.

Many years passed, however, before the potentialities of electric power were realised. The first electric motors were very small and were used only for exceptional purposes. It is on record that as far back as 1879 Sir William Armstrong (later Lord Armstrong) had at his house at Craigside, Northumberland, a water-power plant which generated electricity for lighting his house and also for driving light tools. Ten years later it was still the general impression that electric motors were of value only for driving small machines for which it was not worth while putting down a steam engine. In Mr de Tunzelmann’s volume, *Electricity in Modern Life*, reference is made to the use of an electric motor for working the domestic sewing machine and for driving ventilating fans on board ships and elsewhere. The latter case is emphasised because a ventilating fan was generally fixed in an out-of-the-way place and because it ran at a high speed and could therefore be coupled direct to a small electric motor.

The prevailing impression in those days, and for long after, was that wherever a machine could be driven by a steam engine there was less than nothing to be gained by driving it electrically. The reasoning at the back of this belief was of the plausible kind which carries conviction at first sight. Electricity is generated by steam power ; and in the conversion of mechanical energy into electrical energy there is a certain loss. Secondly, in transmitting electricity from the dynamo to the motor there is a loss of energy due to the resistance offered by the connecting wires to the flow of current. Thirdly, the conversion of electrical energy into mechanical energy in the electric motor involves a loss. Against the electrical method, with its double conversion and its waste of power in transmission, the direct drive from the steam engine appeared to have overwhelming advantages.

This comparison might be accepted as sound and conclusive had we nothing to consider but the direct driving of a single machine. The problem in the average factory is, however, much more complex than that. There are many machines to be driven, and if they are to be driven by a single steam engine they cannot all get the benefit of a direct drive from the engine shaft. Some means of transmitting the power of the engine to distant machines must be provided, and so we find, in the steam-driven factory, an elaborate system of shafting and belting extending along every floor. Each machine is connected to a shaft by a belt which is moved from an idle pulley to a driving pulley when the machine is to be set in motion.

This method of transmitting power in a factory had become so familiar by the time electric motors arrived on the scene that its defects were seldom realised. That it has many defects, and serious ones, will become evident in a moment. Power is needed to keep the shafts, pulleys, and belts moving. Every bearing, however well adjusted and oiled, wastes power. Every belt, however well fitted, wastes power. In a large factory, where there are several storeys, each with long lines of shafting, there is such a mass of metal and such a number of bearings and belts that the energy absorbed in transmitting the power may well be of the same order as that needed actually to drive the machines themselves. Moreover, this waste is going on

steadily all the time the factory is running and whether many tools or few are at work.

James Nasmyth, the inventor of the steam hammer, was so much impressed by this perpetual drain of energy that he tried to avoid it by a drastic change. Instead of using a single large engine to drive all the machinery, he distributed steam from a central boiler to a number of small engines scattered throughout the factory, each driving a single machine or a group of machines. He was enthusiastic about the convenience and economy of this arrangement, but it did not come into general use. The engines, being run without condensers, were inefficient ; their initial cost and the expense of upkeep must have been high ; and the loss of heat in conveying steam in long lengths of piping must have been considerable. Nevertheless, the experiment proved that at least one far-sighted engineer was alive to the serious waste involved in the standard system, and it also supplied a prophetic hint of the principles which were later to be applied with marked success in connection with electric power. Substitute electricity for steam, electric cables for the steam pipes, and electric motors for the small engines, and the typical electrically driven factory appears.

One advantage which Nasmyth's plan secured was a greater freedom in the " lay-out " of the factory and in the arrangement of the machines. The engineer who designed a steam factory of the ordinary kind showed his skill in crowding as many machines as possible on to the shortest system of shafting. We see the effect of this in the old-fashioned factory with its several floors, each crammed with machinery under low ceilings. Space, light, and air had to be sacrificed, and the inevitable result was a dark, dirty, ill-ventilated factory with so little room for the workers in the midst of moving machinery and whirling belts that the elementary notions of " safety first " were out of the question. Only by spending much more money in shafting, and by wasting coal day by day in turning a greater mass of metal round and round, could the factory owner escape from these unhappy limitations. These were the days when everything was put second to economy ; and in the steam factory economy demanded that the factory should huddle closely over the engine that drove it,



ELECTRIC DRIVE IN FACTORIES.

A typical example of "individual drive" where each machine is fitted with its own electric motor, thus eliminating shafting and belting and giving convenience in control and economy in power.

All these difficulties vanish when electric motors take the place of the steam engine with its crude appliances for the transmission of power. The factory can be laid out, not to suit the rigid demands of lines of shafting, but in the manner best adapted to the processes of manufacture. As each machine can, if necessary, be provided with its own motor, it may be placed in the most convenient position, with ample room for the operatives and with plenty of head-room unobstructed by heavy shafts and pulleys. Better lighting and reduced risk of accidents follow.

Most important of all, however, from the standpoint of economy, is the cutting out of the constant waste already emphasised. When driven by an electric motor, a machine absorbs power only when it is working. During idle times, when the machine is being got ready or is undergoing adjustment, the current is switched off. While, therefore, a machine driven from a shaft must be regarded simply as taking more power when at work than when idle, an electrically driven machine takes no power whatever except when it is at work producing goods and earning money.

All the machinery in a factory is very rarely at work throughout the day. Machine tools, for example, have their intervals of rest when cutting tools are being changed and when a finished part is being replaced by one ready for machining. In a carpenter's shop the machine-driven saws and planes work with intervals for the bringing forward of new pieces of wood. Textile machines, printing presses, and many other special types of machinery have long periods of preparation before they embark on a "run." The proportion of idle time varies with the class of work and the skill of the factory organiser, but it usually forms a sensible proportion of the working day, and the greater it is, the greater the economy of doing away with shafting which absorbs power continuously without doing useful work. Where every machine is driven electrically, the call for power rises and falls exactly as the activity of the factory increases and diminishes. The losses in the double conversion are much more than swallowed up in the economy thus secured; owing to the high efficiency of electrical machinery these losses are, in any case, much less than might

be supposed. As for the loss of power in transmitting electricity to various motors in a factory, it is really very slight. Electrical engineers begin to think seriously about losses in transmission when they are dealing with many miles, not with several hundred feet.

We may express the whole argument for the "electric drive" by saying that electricity scores on account of its secondary advantages. Merely to put an electric motor in place of a steam engine may not be a material improvement, but to take a steam-driven factory and reorganise it through and through for electric driving is to capture a host of economies. And apart from the direct saving of power, it brings with it the possibility of greater output and improved quality of product. Just as the conversion of a steam railway to electric traction enables an improved service to be given and more revenue to be earned, so the electrification of a factory raises the standard of quality and quantity.

The output of a machine depends upon the speed at which it can be safely run. This speed varies hour by hour in certain types of machine, according to the nature of the work in hand. For these and other reasons the accurate control of speed is a very important matter; yet with steam power it is a very difficult matter. Theoretically, the engine is governed to make a certain number of revolutions per minute, but in practice it is apt to wobble above and below the standard. When the load is light the speed tends to rise, and when it is heavy the engine slows down. Between the engine and the machine, moreover, there are many links which are weak in maintaining speed. Under heavy or fluctuating loads the belts tend to slip, thus affecting the speed of every driven shaft. When we come to the machine itself we find that speed variations are obtained by means of stepped pulleys or change-speed gears; that is to say, we get speed changes in jumps, so that intermediate speeds are unobtainable.

It is not too much to say for the electric motor that it will give precisely the most efficient speed required under any conditions of operation. In the type of motor generally used for driving machinery, the design is such that the running speed is practically constant under all loads. If the load in-

creases, the motor uses more current ; and if the load eases off, the motor takes less current—always, however, doing the same number of revolutions per minute. The speed can be diminished by introducing an electrical resistance into the circuit of the motor. This can be done in various ways, either in a large number of short steps or with perfect smoothness from full speed down to an almost imperceptible “crawl.”

Of late years many refinements have been introduced in connection with the speed control of electric motors. Variable speed motors have been designed to give the range of speeds required on certain machine tools ; and the type of motor adapted to each class of machine has been very accurately determined. The motor controller itself, which began with the simple regulating resistance we have just mentioned, has been developed with great ingenuity in many directions. A typical example is the “push-button” control on a printing press. All that the operator has to do in starting the press, running it slow, speeding up to the highest rate, or stopping instantly, is to push certain buttons. He can also, by the same means, carry out the process known as “inching,” that is to say, moving the machine for a very short distance. This process, which has to be repeated frequently in making a printing press ready, is very difficult with mechanical drive, but becomes as simple as possible with this form of electric control.

In certain machine tools, again, where a cycle of operations is repeated over and over, automatic electrical control has been applied. Planing machines, for example, have to move the work slowly under the tool and bring it back quickly again for another working stroke. By means of special electric gear this is done with perfect accuracy and with the minimum loss of time, without the intervention of the operator. A more familiar example of the same sort of thing is afforded by the automatic lift, in which all the operations of opening and shutting the gates and ascending or descending to certain floors are performed under safe conditions merely in response to the pressing of buttons.

These developments of electric motor control are mentioned to prove that there is a great deal more in electric driving

than merely turning a wheel at a lower cost than can be done with steam.

Ease and accuracy in speed control are not, however, the only causes of the more efficient working of electrically driven machines. In many cases it is possible to run a machine faster by electric motor than from a steam-driven shaft. This is due to the perfectly even turning movement of the electric motor. The ordinary steam engine does not give this even movement, in spite of the heavy fly-wheel which is introduced to equalise the variations. Between the engine and the machine, as we have noted, there are many causes of irregularity; and the upshot is that a speed chart taken on the machine itself would show a wavy line instead of a straight one. It will be readily understood that in textile machinery, where many delicate threads are involved, such variations in speed are liable to cause breakages and unevenness. With electric motor drive, on the other hand, the speed line is practically straight. The machine can be safely run faster, and gives a larger output of a better quality of material.

Perhaps the clearest proof of this claim lies in the efforts made in mechanical driving to meet it. Textile mills used to be driven by low-speed horizontal reciprocating engines—magnificent in their proportions and a source of intense pride to their makers and users. The main drive was by ropes running on grooved pulleys. In some mills these mammoths of the steam age have been replaced by high-speed steam turbines driving the main rope system through speed-reducing gear. Both space and steam are saved in this arrangement, and it is also claimed to drive the machines almost, if not quite, as evenly as the electric motor. It does not, however, afford all the advantages of electric driving; and practically every new textile mill is electric throughout.

Among these advantages there is one, not yet described, which is rather primary than secondary in character. The designer of a steam-driven factory worked very much by rule-of-thumb in deciding the power required in his engine. He had only a general notion of the horse-power needed to drive each machine, and he had to guess at the additional power absorbed in belting and shafting. To be on the safe side,

therefore, he had to provide a margin of power in his engine, thus increasing the cost and reducing the efficiency of the equipment. With electric driving, on the other hand, tests can be made to ascertain exactly the size of motor for each machine ; and the total horse-power required is found simply by adding together the horse-power of all the motors and making a slight but definite allowance for the loss of power



AN ELECTRIC CRANE AND LIFTING MAGNET COMBINED

The mushroom-shaped magnet holds a large steel ball which, when the current is switched off, falls on the heap of scrap-iron, and smashes the large pieces into small fragments convenient for melting down in the furnace.

in the wires leading from the source of power to the motors.

The benefit of accurate measurement does not end at this point. It is very important for the works' engineer to know whether his machines remain in good condition. When lubrication is deficient, when bearings become worn, or when any parts of the machine get out of adjustment, more power

is needed for driving. With the old-fashioned drive through shafts from an engine there was no way of detecting these minor sources of waste, which might, in the aggregate, grow to a serious amount. The engineer would notice that he was burning more fuel to keep the works going, but he would be unable to discover which machines were responsible for the loss. Again, the small troubles referred to are precisely those which, if undetected, will grow and grow until they produce



ELECTRICALLY DRIVEN TRANSPORTER
Capable of handling 150 tons of coal per hour.

a breakdown. On more than one ground it is most useful to be able to test the working of any machine at any time.

With electric driving, the test can be made quickly, simply, and accurately, by measuring the current taken by each motor. The right current consumption is known; and if the test shows that it is exceeded the engineer gets a definite warning to examine the motor and the machine, so applying the stitch in time. The electric motor thus lends part of its reliability to the machinery it drives. In some factories special testing

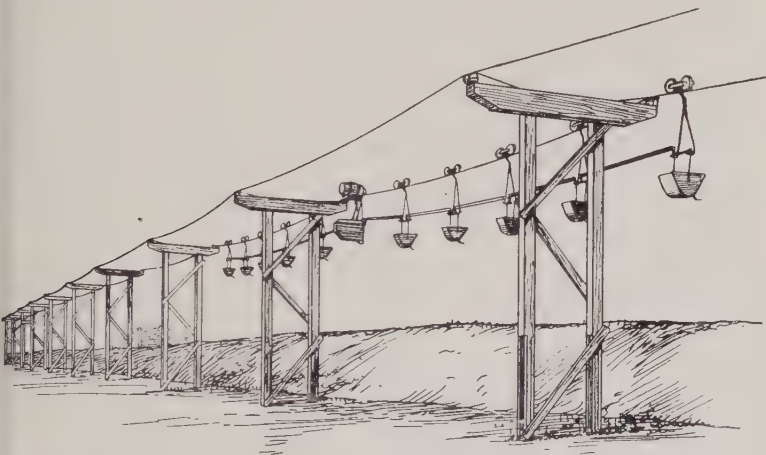
boards are arranged at convenient spots throughout the works so that several circuits may be examined in rapid succession from one point.

A further refinement has been developed in factories engaged on mass production. Each section of the works is connected to a recording instrument in the manager's office, and the instrument traces on a chart a line which shows how much electrical energy each section has taken at any time during working hours. Assuming that the machinery is all in good working order the line on the chart is an index to what the output of each section ought to be. If the output is not as good as the chart indicates, there is clearly some inefficiency which requires investigation. By this means the manager keeps his finger on the pulse of the factory and obtains the earliest symptoms of trouble. The same guide is invaluable in keeping the various departments in step, as it were, since the success of mass production depends largely upon each department producing its quota in a certain time. Otherwise a large part of the factory may be held up for lack of a sufficient number of some trifling item.

Already we have travelled a long way from the simple question of turning a wheel more efficiently by electricity than by steam, but we have not come near to the end of the advantages of electricity in the factory. A full discussion of these advantages would involve a survey of every industry, because each type of industrial operation brings out a special phase of the economy, adaptability, and convenience of the electric drive. All that we need do here is to take some of the more conspicuous examples so as to round off the claim that electricity is destined to become universal in engineering and other industries.

The various benefits we have described were not all discovered when the electric drive was young. They grew out of experience based on trial and error. Naturally enough, electric power was applied in those cases where its advantages were most marked. The ship ventilating-fan previously mentioned is a good example, since the proper place for the fan is a remote corner where a steam engine could hardly be put. Another good example is the overhead travelling crane which

rides on girders from one end of a factory bay to another. It is a perfectly simple matter to supply the crane with electricity by means of sliding contacts similar in principle to those on a tramway system ; and it is easy also to equip the crane with driving and control gear which enables one man to carry out, rapidly and accurately, all the operations of lifting a load, conveying it to any point within the four corners of the factory, and lowering it where required. The difficulty of doing the same thing by any other means is so formidable that the attempt is never made, even in gas works, where there are at



ONE OF THE EARLIEST APPLICATIONS OF ELECTRIC TRACTION

The overhead runway or "telpher," erected at Glynde, in Sussex, for the transport of material from a quarry. Automatic electric arrangements were made to prevent one train of "cars" colliding with another

least sentimental reasons for doing without electricity if anything like a decent substitute can be obtained.

The overhead travelling crane is typical of a large class of machinery, in which power-driven mechanism moves at a height and over distances which render the use of a steam or gas engine practically impossible. One of the earliest industrial uses of electricity was in driving the elevated conveyer known as a "telpher" line. The cars or conveying units hang from an overhead rail along which they run on small wheels. On the first system of this kind, erected in the early eighties

at Glynde, in Sussex, a locomotive hauling several cars was employed to carry clay from a pit to a railway over ground which was frequently under water and therefore unsuited for the usual form of transport. This line was notable not only because it was a pioneer, but because the electric power transmission was arranged to give an automatic protection against the collision of trains—a very good example of the important secondary advantages arising from the use of electricity.

Electric telfer lines—or overhead runways, as they are more generally called—are now frequently used in factories for conveying materials and parts from one department to another. By their use, the ground is kept free from obstruction, and sharp curves can be negotiated with ease and safety. The travelling mechanism is controlled sometimes by a man who rides on it, and sometimes by means of cords suspended within reach of an operator on the ground. The ability to apply power at any point where wires can be led is also used in numerous forms of conveyer in which the motor itself is fixed. One form which is common in power stations employs a series of buckets, suspended at intervals on an endless chain, to load the bunkers with coal and to carry the ashes off to the dump. Another form is the band conveyer, in which such materials as ore or broken stone are carried on a broad belt driven by electric power.

Although the portable electric tool was not developed to any great extent in the early history of industrial electricity, it may be mentioned at this point because it illustrates the same advantage as the electric crane or runway. Where power is conveyed by means of shafting every tool must be fixed, and the work must in all cases be brought to the tool. Frequently it happens that minor operations, such as drilling a series of holes or grinding surfaces, have to be performed on a heavy casting. In such cases it is an immense advantage to use a portable tool so that the casting need not be moved about; and there is no more convenient form of portable tool than one in which both the tool and the driving mechanism are combined, as in the electric drill and the electric grinder. Power is conveyed to the tool by means of a trailing flexible cable. Heavier portable machines, such as electric riveters,

are also used, being conveyed to their work by means of a crane.

Almost the first industry to be systematically converted to electric working was coal mining. Here the conditions were heavily in favour of electricity. The power for working a pit has to be produced on the surface and conveyed down a shaft



ELECTRIC MOTOR AND TOOL IN ONE

The portable electric drill which does its work in any position. Current is conveyed to it through the flexible cable.

several hundred feet deep and along tunnels for many hundreds of yards, to be used for pumping, haulage, ventilation, and other purposes. The usual practice was to carry steam pipes to every point where machinery was in operation ; and very little knowledge of the habits of steam is needed to realise something of the enormous waste involved. Compressed air and hydraulic power were also used to some extent, but these had their limitations and disadvantages. In such circum-

stances the employment of electricity was as good as obvious, especially in view of the necessity of opening up the deeper seams of coal and extending the workings to ever greater distances from the source of power.

An electric generating station was therefore erected close to the pit-head, and large cables were carried down the shaft, with branch cables along the various workings. The loss in electrical transmission, even to remote parts of the mine, was negligible in comparison with the waste of energy in other systems. The convenience of dealing with flexible cable instead of rigid pipes ; the compactness and ease of control of motor-driven machinery ; these and other factors led to great economies in the working of mines. Electricity, moreover, gave a great impetus to the use of mechanical coal-cutters, which effect an increase in output at a diminished cost. The miner does not, perhaps, appreciate the virtues of the electric coal-cutter as much as they deserve, and he certainly makes the most of the dangers of shock which attend the use of electrical apparatus in a confined space. But the characteristic attitude of the manual worker towards all labour-saving appliances has only restricted, not prevented, the use of this rapid means of winning coal.

In the early diagrams of electrified coal mines there were generally shown two engine houses at the pit-head—one the electric generating station, and the other the steam-driven plant for raising and lowering the cage in the shaft. Up to the present day, moreover, the steam winding engine survives in many pits otherwise operated by electricity. There were several reasons for this exception. In the first place, no transmission of power was involved ; the engine drove directly the drum on which the wire rope supporting the cage was wound. In the second place, steam driving was well adapted to give the strong, steady pull necessary to overcome the inertia of the heavy mass of the drum and the cage with its heavy load. It was difficult to see how electric driving could, under these conditions, give greater economy and a higher winding speed. In time, however, the problem was solved by the design of a special electric winding gear in which an auxiliary fly-wheel was used to store up energy to be drawn



AN ELECTRIC WELDER AT WORK ON POTS AND PANS

Here it is shown fixing a handle to a saucepan. Some samples of its work are seen in the foreground.

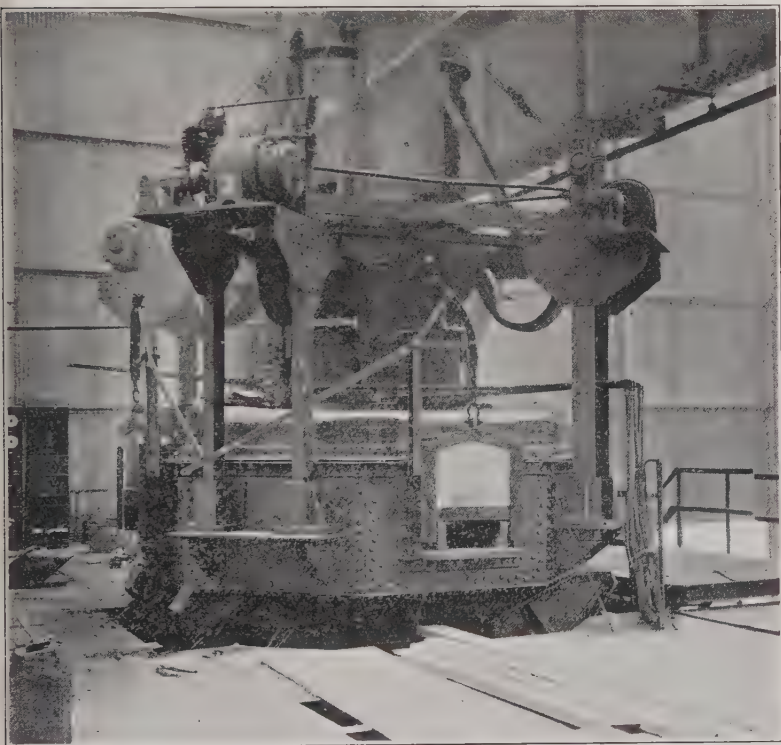
upon in starting the cage on its upward journey, thus avoiding a heavy rush of current. Smooth and rapid operation was secured, giving an increased power of raising coal.

The general conditions which led to the use of electricity in coal-mines apply to other mines and to quarries, brickworks, tunnel excavation, and all other cases in which the power-using machines are widely scattered or in places difficult of access. In one important respect the coal-mine is the most difficult problem for the electrical engineer, on account of the danger of explosion in fiery mines. Elaborate precautions must be taken to prevent any electric spark or flash igniting the gas in the mine. On the whole, these precautions have been wonderfully successful, but the necessity for them has opposed the extension of electricity in one or two directions. The pit pony survives in many mines because the electric trolley locomotive is considered too dangerous. Where there is no danger of explosion, however, battery locomotives can be used in place of ponies, with great advantage in economy and convenience. Pit ponies are generally sleek and apparently contented, but their existence is associated with an uneasy sense of cruelty ; and where they can be replaced by electric haulage the sooner the change is made the better.

In non-fiery mines electric lighting can be freely applied in the ordinary way, the workings being illuminated by lamps suspended at intervals from the roof. Where gas is present, however, the miner must depend upon a lamp which under no conditions will yield a spark. For this purpose the electric safety lamp has been devised. It is a portable lamp containing a small storage battery which supplies current for eight hours or more to a tiny electric bulb ; and the whole design is adapted to give complete safety even if the bulb is smashed. We mention this detail not because of its intrinsic importance in rounding off the applications of electricity in mining, but because the use of the electric lamp has opened up a way to relieving the miner of one of the most serious risks of his calling. " Miner's nystagmus " is a distressing form of eye trouble which affects the nervous system, causing chronic despondency and leading to total incapacity for work. Its main cause has been traced to the deficient illumination pro-

vided by the old type of safety lamp. The introduction of electric lamps in several mines has greatly reduced the number of cases and gives hope that this melancholy disease will become extinct.

This, by the way, is an electrical application which the miner fully approves. In a Scottish mine, where a charge of nine-



One of the large electric steel-making furnaces which did such excellent work during the war. It is capable of melting twelve tons of steel.

pence per week is made for electric lamps, the money is paid cheerfully, although oil lamps are available for nothing. No testimonial could be more convincing.

The industrial applications of electric power which we have mentioned are only a few out of a multitude, but they are typical of the way in which the electric motor adapts itself to

all kinds of work. On the one hand we find an electric motor, rated at one-sixteenth of a horse-power, driving a dentist's drill; and on the other hand we have a motor, capable of developing over 20,000 horse-power, driving the rolling mills in a steel works. Between these two extremes we have electric motors fulfilling all sorts of conditions—the even-speed driving of textile machinery, the variable-speed operation of machine tools, the intermittent work of lifts, and the continuous work of pumping. There is no other type of machine which remains efficient over so wide and so varied a range of duties.

There is, moreover, no machine which can rival the electric motor in convenience of application. It can be mounted direct on the machine to be driven; it can be placed on the floor, or on a wall bracket, or suspended from the ceiling, or housed in a pit beneath the floor. Starting, stopping, and other operations of control can be performed from any point, and with an ease and accuracy which no other system of driving can equal. This quality of convenience, combined with reliability, makes the electric motor ideal for industries which need power but do not want to employ trained engineers merely to look after the application of the power. For example, in a clothing factory all the cutters and the sewing machines can be electrically driven in so simple a manner that the control can be kept in the hands of the operators themselves. The presence of a skilled electrician is not necessary except for occasional visits to inspect the motors and give them the oiling and cleaning and other superficial treatment needed to keep them running sweetly. The wise electric power user arranges a maintenance agreement as a moderate fee with an electrical firm and thus relieves himself of all anxiety about the running of his factory.

The same qualities have made the electric motor very popular in business establishments where the use of power is incidental. The butcher with a mincing machine, the provision merchant with a bacon cutter, the grocer with a coffee grinder, the restaurant with service lifts, the hotel with boot-cleaners and plate polishers, the dairyman with a cream separator, the jeweller with a buffing and polishing lathe, the boot-repairer with stitching machines and grinders: these are

typical cases where manual labour *can* do the work, but where a compact and efficient machine is a great advantage. Similar cases in the domestic sphere will be described in a later chapter



An example of how readily electric power may be applied to isolated machines. A pneumatic power hammer driven by an electric motor.

and will emphasise the manner in which the electric motor reduces the power problem to its simplest terms. With electricity at command, the pressure of a button or the moving of a switch handle achieves rapidly and perfectly

an operation which otherwise would involve much time and labour.

Trifling as these examples are, both in the amount of power involved and the purposes to which it is applied, they take us to the very heart of the meaning of electric power. All material progress consists in getting an instrument to do the work of the world better than it was done before—quicker, more accurately, and with less expenditure of human energy. In ancient times the instruments available were primitive and the labour required to operate them immense. The Pyramids are marvels to us not because they reveal a high degree of engineering science among the Egyptians, but because they show what difficulties could be overcome by unlimited drafts upon the strength of human beings.

Between the Egyptians and the ant colony, in which each busy individual in a multitude of helpers contributes his grain to a monument of labour, there is not much difference in principle. To-day a building rises from its foundations with a celerity of which the ancients never dreamed save when they dreamed of genii; and it does so by virtue of *power* which the human hand controls with greater assurance than any hero of the *Arabian Nights* called upon his demons. An electric crane towers over the site, raising beams of steel shaped by electric power, or blocks of stone quarried electrically and trimmed by electrically driven machinery. Concrete mixers, driven by electricity, pour out the material by which the steel skeleton of wall and floor is clothed. Doors, window frames, and panelling are the products of power-driven machinery; and the innumerable details which go to complete a habitable structure bear witness in their various ways to the same agency. When we visit the Pyramids we people the scene with myriads of slaves toiling at ropes, straining at levers, and patiently chipping at monster blocks of granite. Surrounding the modern building we see in imagination the coal-mine, the iron and steel works, the quarry, the cement factory, the timber yard, the brick field, the brass foundry, the glass works, the electric cable factory; these and a thousand other centres of power. Man moves among them—toiling, it is true, but toiling less than the slave under the Egyptian sun, and always

contriving to place more and more of the burden of labour upon the machinery he controls.

The ultimate aim of this progress in power, which reaches its highest yet-attained point in electricity, is the conservation of human life. Once upon a time men sought redemption from the curse of labour by making others work for them; freedom for the few was thus built up on the slavery of the many. What the engineer, and in particular the electrical engineer, now seeks to achieve is the liberation of all from the burden of stultifying toil by turning power to account, not in this or that exceptional direction, but for every purpose which absorbs time or energy which might be devoted to a higher purpose. He seeks to do this by multiplying the services of electric power, by extending its supply, and by adding continually to the means by which electricity may be pressed into the service of man. In short, he proposes to invest the wealth of the world in machinery, so that the return upon human life—the most precious and the one irreplaceable form of wealth—may be enhanced.

This is a theme which will be developed more fully later on in connection with the domestic uses of electricity, the development of communication, and other phases of electricity in action. The keynote, however, is struck by industrial electric power; and it is in the electrically driven factory, with its activity maintained by energy which a man controls as easily as he raises his arm, that we begin to realise the meaning of the all-electric age.

CHAPTER VI

THE GROWTH OF CENTRAL POWER STATIONS

IN discussing the industrial uses of electric power no mention has been made of the source from which the electricity was drawn. To a large extent the benefits of driving machinery by electricity are independent of the question whether the factory has a generating station of its own or whether it takes current from the public supply. This question, however, raises many important issues in connection with the development of a cheap and abundant supply of electricity.

We have already noted that in the ordinary run of factories the machines are at work intermittently. Cases do occur where certain plant is never still throughout the working day or, indeed, at any time night or day. For example, the pumps and ventilating fans in mines are kept running continuously; and in factories the motors driving conveyors or exhaust fans for removing dust or fumes created in the processes of manufacture are always busy. These are exceptions, and it generally happens that when one machine is at work another is idle. At intervals all the machines may come on together, and at other times very few may be taking current.

If we make a chart to represent the fluctuations of the total demand for power in any factory, it will look like a range of mountains. The valleys indicate when few machines are running, and the peaks occur when many machines give a simultaneous demand for power. Whatever source of power we employ, it is clear that it must be equal to surmounting the highest possible peak. On the other hand, it is equally clear that the *average* power required is much less than the power required at the higher peaks. The average would be

represented by the straight line obtained by cutting off the peaks to level up the valleys, making a plateau in place of a mountain range.

Assuming that the factory makes its own electric power, the generating plant must be powerful enough to supply the maximum demand. That is to say, it must be more powerful—therefore larger and more expensive—than is required for the average demand. Every engine works most efficiently when meeting a certain demand, which we may call its normal load. If the load is less than the normal, the engine runs “light” and becomes less efficient. The upshot is that an engine capable of keeping the wheels moving at the heaviest load is running wastefully during the periods when a valley appears on the chart.

This drawback is mitigated by the ability of a steam engine to take an overload. The engineer can therefore install a generating plant with a normal capacity below the maximum, trusting to its power of giving an abnormal amount of energy to carry it over the occasional peaks. With gas engines this measure of relief is not available, because gas engines are able to take very little in the way of overload. But even with steam engines the overload capacity only partly meets the difficulty of finding a source of power which will economically meet all the ups and downs in the load. To take a concrete example, the load may average 3000 horse-power and rise frequently to 6000; and the engine installed may have a normal capacity of 5000 horse-power. Only spasmodically will the engine be running under the most economical conditions, represented by a load of 5000 horse-power.

Generally speaking, the larger the factory and the more varied the operations carried on in it, the less the difference between the average demand and the maximum demand is likely to be. A small printing works with a single machine will give rapid fluctuations between the maximum demand and nothing at all; add a number of other printing machines of various kinds, a few linotype machines, stitching machines, guillotines, stereotyping plant, paper-baling machines, and so on, and their several demands, rising and falling at different times, tend to fill up the valleys. Carry this still further, to

a large works with a foundry, a pattern shop, an engineering shop, an assembling shop, each with its different types of machine and its complement of cranes or conveyers ; in doing so we multiply the chances that one demand will dovetail into another.

The extent to which they do dovetail in this way gives what is known as the " diversity factor "—a phrase which is often in the mouths of electrical engineers and is apt to be strange to the layman who has not reflected on the problem of meeting the demand for power in the most economical way. When, however, the elementary facts of that problem are considered it is not difficult to see that demands which succeed each other are much easier to meet than demands which are piled up upon each other at certain periods with blank spaces between.

Our argument, so far, has led us to the point that a factory with many diverse loads can be supplied with electricity more economically than a factory with only one or two types of demand. A large factory with numerous departments is, however, essentially the same as a number of factories grouped together. What our argument really means, therefore, is that current can be supplied more efficiently to a group of factories than to a single factory. There is economy in numbers, largely because every new factory that is taken on tends to average the load on the generating plant and to put the supply of power on a more efficient basis.

This argument has to be carried only one or two steps further to bring us to the conclusion that the proper way to supply an industrial town with electric power is from a central station. Instead of each factory having its own small generating plant, power will be produced at one large plant and distributed through mains to the various factories. This, it will be remembered, was the law of progress in connection with electric lighting and electric tramways ; many small local sources of power gave place to one source doing business wholesale. Even in the case of electric lighting alone, where there is no diversity of demand—nearly every user being liable to switch on when darkness falls—the erection of a central station was found to pay. Still greater benefits result from centralisation when the various users supplement each other's

demands to give a more even and continuous load on the plant.

Before tracing the remarkable effect which the industrial power business had on the growth of public central stations, it will be useful to consider how the taking of power from an outside source benefits the manufacturer.

Factories which have their own generating plant often produce very low estimates of the price which their power costs. These estimates, however, are not always complete, and they can never be much more than estimates. There are many half-hidden expenses which are apt to be ignored. For example, such items as fuel, water, lubricating oil, and wages are obvious enough and can be closely determined; interest and depreciation on the plant can also be allowed for on broad lines; but full allowance is not always made for the space occupied by the plant, the cost of supervision, the expense of removing ashes, and the item of repairs. These and other matters are often lumped with the general expenditure of the factory. Some allowance should also be made for the risk of obsolescence—the risk that the progress of invention will make the plant almost worthless in the market, although it is still in sound working order.

When power is taken from the public mains all this capital expenditure, with its contingent cost and risk, is avoided. The factory pays a definite sum, not for something that will produce electricity, but for electricity itself, which is metered as it comes into the factory. Weekly—or, if necessary, daily—readings of the current consumption can be taken; whereas with generating plant at the factory it is impossible to discover, save over long periods and after careful calculation, what the real cost of running the factory may be. In the previous chapter we noted the advantage of being able to check the efficiency of each electrically driven machine. Where electricity is “on tap,” it is possible to extend the same measure of accurate control to the entire factory, so that any waste may be immediately detected.

Another point of importance is that the multiplication of small independent stations means waste of capital. It is to some extent a waste of capital for the individual factory,

because the owners have to find money, and pay interest on it, for plant which is not absolutely necessary to production. That is to say, their financial burden would be lightened if they did not invest in a power station. Alternatively, they would be better off if they spent the money on machinery which would directly increase their output. This aspect of the case becomes more important on crowded city sites, where it is of great advantage to use every inch of space in the most remunerative way. Separate generating plant means that valuable space has to be given up to the production of power which may be obtained simply by tapping an electric main in the street outside.

On a broad scale the saving by centralisation is more direct. Each factory which makes its own power must, as we have seen, install plant large enough to cope with the maximum possible demand. Two hundred separate factory installations would have a total capacity of two hundred maximum demands added together. But by erecting a single station to serve the two hundred we take advantage of the fact that all the maximum demands do not, in practice, occur at the same moment. Therefore the central station does not need so much horsepower as the two hundred separate plants added together. Here we have a distinct saving in first cost, to say nothing of the lower fuel costs and other running expenses.

It is putting the case at its lowest to say that each factory making its own power must instalated plant equal to the maximum possible demand. In order to be sure of a supply at all times, some provision must be made for the risk of breakdown. The only complete provision is a duplicate generating plant, thus doubling the capital cost of that part of the equipment. Consequently the necessity of providing a stand-by in case of failure is a heavy burden on the small station. Let us imagine, however, that the two hundred stations are linked together with electric mains, so that they can come to each other's aid when accidents occur. None of the stations need then put in any stand-by plant, because it could always draw upon the other one hundred and ninety-nine. This advantage is essentially what is secured when the two hundred draw from a central station. That station does not depend upon a single

generating set. It contains several ; and, in the event of one of them breaking down, the others can, by virtue of their overload capacity, carry on until the repairs are effected. Generally, however, the central station engineer retains a certain amount of generating plant as a stand-by, to give additional security of supply in an emergency. The usual practice is to keep in commission some of the earlier plant which is, strictly speaking, obsolete, owing to its being less efficient than the later plant. Whatever plan be adopted, the central station is able to provide an adequate stand-by at a much lower cost than the total of two hundred separate stand-bys.

As regards reliability of supply, the central station has a further advantage. The regular and efficient working of machinery in a generating station demands constant skilled attention, which is not easily given by a factory engineer who has to divide his time between the station and all the other departments. For the economical use of fuel and the care of details of running he must rely largely upon the competence and integrity of the men in charge. With good luck he will get good results ; with average bad luck he will get nothing better than ingenious excuses for waste and interruptions. Conditions in a central station are radically different. The plant is under the sole control of an engineer who is not a works' engineer, or a mill engineer, or anything but an electrical engineer who has risen step by step and year by year to a position of full authority. Each man under his command is trained for his particular duties ; and the whole station, from the coal pile to the ash heap, is organised for efficient working in every detail.

It would be absurd to claim that every central station engineer is as clever as he ought to be, or that every public generating station is a model of economy and organisation. But the odds are certainly in favour of better results being obtained by people who specialise in the production of electricity. The engineer of a motor-car factory, or a soap works, or a mill, may or may not be competent to run electrical plant ; the men who are put in charge of public plant costing hundreds of thousands of pounds are carefully chosen on the

ground of their competence for that particular job. Moreover, the results they achieve are closely scrutinised by the local authority or the company owning the plant, and there is keen competition among central station engineers to show the best records in economy. All these factors tend to efficiency, and they are factors which do not apply to the electric power plant which is tacked on to a mill or a factory.

In central stations, too, there is constant supervision of the work of the staff and a constant check on the working of every part of the equipment. Detailed records are kept as a matter of routine, so that the chief can put his finger immediately upon any item which is not up to standard. With a small factory station the tendency is to simplify matters as much as possible, so as to keep down initial costs and the weekly wage sheet. Measuring and recording instruments which throw the light of scientific accuracy on what is happening in furnaces, boilers, and engines, are looked upon as refinements which are a luxury for a station with only a few hundreds of horse-power. The large central station, on the other hand, finds the cost of installing these instruments very small in relation to its total capital expenditure, and it also finds them a very remunerative form of insurance against small daily waste which mounts up to a huge total at the end of a twelvemonth. It pays a large station to test the heat value of its coal, to measure the percentage of ash which remains after the coal is burned, to weigh the coal as it enters each boiler, to examine the flue gases to detect any imperfect combustion, to measure the flow of steam, and generally to bring scientific precision into every section of the station. Some of the giant power stations of to-day go so far as to appoint a highly paid expert to look after the boiler house alone.

The need of simplification in small stations also leads to an almost complete reliance upon manual labour in the boiler house. Coal is shovelled into the furnaces, which are stoked—not always skilfully—by hand. The ashes are likewise removed in the primitive way by shovel and barrow. Where operations are carried out on the large scale it becomes profitable to use electric power for these purposes. A whole wagon-load of coal can be tipped, within a few seconds, into a hopper

and carried thence by a bucket conveyer to bunkers over the boiler ; the coal descends by chutes to automatic stokers, and the ashes which fall from the grate are carried by the conveyer or by a pneumatic suction plant to the ash heap, where they can be loaded by means of a crane into wagons for removal.

A large power station is, in fact, a collection of machinery run by machinery. Nothing strikes the visitor to such a station more forcibly than the contrast between the size and elaboration of the mechanical equipment and the smallness of the number of men engaged in controlling it. Thus the evolution of the power station itself illustrates the advance which we described at the end of the last chapter—the advance from manual labour to machinery, from a low stage of efficiency to a high one.

We have by no means exhausted the list of reasons for claiming that the central station affords a cheaper source of supply than the small factory plant, but we have perhaps said enough to explain the marked tendency to rely more and more upon central stations for a cheap supply of electricity. This policy of taking electricity “ on tap ” has, however, advantages beyond those of economy. It is, in the first place, a great convenience for a firm to be able to concentrate on its proper business of making furniture or screw nails or carpets, and to leave the making of power to those who are experts in that direction. Again, the source of supply afforded by the public mains is, under normal conditions, practically unlimited. A factory which generates its own electricity is under a heavy disadvantage when it wants to make extensions. Its generating plant is suited to the existing demand and will not be able to cope with the added load, which can therefore be met only by installing a small (and uneconomical) generating set or by replacing the generators by larger ones. The alternative is embarrassing, because either course involves a sacrifice. On the other hand, a factory which takes power from the public mains can obtain more current without difficulty. It draws upon a source which is always—again under normal conditions—developing ahead of the probable demand. In drawing still further upon this source it stands a chance of getting its current at a cheaper rate, because of the increase in the amount

of electricity purchased and also because the addition may make the load more diversified and therefore more favourable to the power station.

The phrase "under normal conditions" has been emphasised on account of the famine in power created by the War. Ninety-five per cent of the munition factories erected during the War were electrically driven, and most of the existing factories of all classes multiplied their demand for electric power. These developments occurred when generating plant was difficult to procure, with the result that both during and after the War the public central stations were heavily overloaded. It is an astonishing fact that between 1914 and 1918 these central stations doubled their capacity for producing electricity. They made as much advance during these four years as they had done between 1914 and the earliest days of the industry. Yet, so great was the continuing demand for electric power, this rapid increase did not keep pace with the needs of the day; and since the War strenuous efforts have been made to restore the normal balance of supply and demand. As we shall see later, these efforts were a prelude to further developments on an unprecedented scale.

In the above discussion of the advantages of taking electricity "on tap" it has been tacitly assumed that the whole factory is at work all the time. In practice, however, it often happens that one or two departments have to be kept going while the others are shut down. The assembling shop, for example, may be working overtime to complete urgent contracts, or the machine shop may be running on a night shift to enable its output to keep pace with the rest of the production. In such cases the demand for power is relatively small, and if the factory depends upon its own generating station the plant will then be running "light" and inefficiently, adding heavily to the cost of overtime. Where, however, power is taken from the public mains, one section or even one machine can be kept going economically. The power is *there*, at any time and in any quantity, for any machine or group of machines. The consumption of current therefore follows exactly the fluctuations in demand, and there is no falling off in efficiency at light loads.

On the broad question of independent generation or power "on tap" for factories there is one rather subtle result of a choice one way or the other. When a factory owner has to lay out capital in a power station with boilers, chimney-stack, engines, generators, and other expensive plant, he is inclined, consciously or unconsciously, to cut expenses in connection with motors and control gear in the factory itself. The most tempting way to save initial cost is by using one motor to drive several machines instead of giving each machine its own motor. It will have been gathered that the "one machine, one motor" system—which is known to engineers as the *individual drive*—is ideal in the matter of running economies, because it cuts out all waste of power in shafting and makes the power used exactly what is needed by each machine in its productive work. On the other hand, the *group drive*, in which a number of machines take power from a shaft driven by a motor, costs much less to install, and the factory owner has to balance the day-by-day economies of the individual drive against the larger interest which is payable on the more costly installation.

Where a number of tools, such as a range of automatic lathes, are run almost constantly at a fairly uniform load, it may be cheaper in the long run, as well as in first cost, to drive them all from one motor. But most machines, as we have noted, work intermittently, and careful calculation will show that as a rule ultimate economy is best served by giving each machine its own motor, especially if full advantage is taken of refinements in control. There is, however, no hard-and-fast law in the matter, and plenty of engineers are ready to make the most of "special conditions" to justify the adoption of the old familiar, simple, and cheap system of driving from a shaft. The arguments thus advanced find a fertile soil in the mind of the manufacturer who has spent many tens of thousands in electrical plant apart from the actual equipment for driving his machinery. Conversely, the manufacturer who takes electricity "on tap" has to consider the driving equipment only, and is therefore more ready and able to lay out capital in providing his works with the most efficient system.

It is not very easy to convince the layman that by installing more electric motors a power user will consume less current.

He suspects a fallacy behind the arguments which the electrical engineer advances so plausibly. To take a typical case of this natural scepticism, a firm which had bought an electric printing works and transferred the plant to a new building was thunderstruck to find that the consulting engineer proposed to put in motors with a total horse-power far in excess of all that the old works had contained. Instead of a few motors driving all the machines from shafting he specified one motor for each machine. The firm had an inner conviction that more motors meant bigger bills for current, but it wisely did as the expert advised, and found eventually that more motors meant much lower bills. In the old works the motors had been running practically all through working hours, while in the new works each motor was switched on only as and when required.

Through most of the argument in this chapter we have assumed that the factory in question was of some size, so that the notion of putting in generating plant of its own was quite plausible. We may recall, however, that the earliest applications of the electric motor were in cases where the plant was so small that using a steam engine to drive it did not seem worth while. Electrical history has kept on repeating this original phase in multitudes. The great majority of power users need only a small amount of energy. Bakers with one or two dough mixers ; blacksmiths with a forge-blower and perhaps a small power hammer ; dairies with refrigerators and cream separators ; stationers' shops with one or two machines for printing and die-stamping notepaper ; garages with a few lathes and drills ; carpenters' works with a circular saw and one or two wood-working tools ; clothing manufacturers with a few rows of sewing machines : these are some of the more familiar members of a huge tribe of small power users. To them the benefits of electric power "on tap"—the convenience, the saving in space, and so on—are as manifest as the disadvantages of being compelled to install and operate a prime mover.

We may now turn to the point mentioned in the earlier part of this chapter—the effect which the industrial power business has had on the growth of public central stations. The advantage of adding the tramway load to the lighting load was

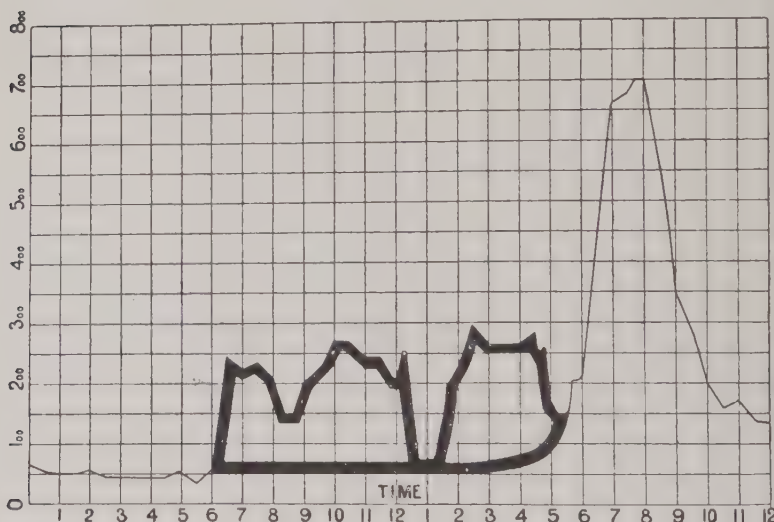
previously discussed ; and the benefits to be gained by centralising the supply of power for many factories have also been explained. Is there anything further to be gained by combining the traction, lighting, and industrial loads ?

Only a slight effort of imagination is needed to realise how the demand for industrial power dovetails into the other demands. By tracing the regular course of a working day it will be seen that the various demands which a workman makes on a central station succeed each other. On rising in the morning he switches on the electric light and, if he is an up-to-date workman, cooks his breakfast on an electric stove. When he leaves his home the lights and the stove are switched off, and he boards a tramcar or electric train, thus increasing the traction load. Some minutes later he arrives at the works and starts his machinery, which remains in operation until the lunch hour. In certain towns the workmen go home by tramcar to their midday meal, so that the switching off of the machinery is followed by an increase of the load on the tramways. This increase subsides before the works are re-opened to provide an industrial load which continues until the late afternoon period when the homeward tide from office and factory begins to flow and when the lighting demand is beginning to become heavy.

The tendency, therefore, is for the factory demand to fill up some at least of the valleys in the chart representing the day's work of a central station. Not in every case, we may again mention, does this dovetailing occur so neatly. On a dark winter's afternoon the factories will pile a lighting load on the top of a power load while most of the buildings in the town are also using electric light. A heavy fog will cause a " peak " to rise on the chart at any time of day by adding a sudden lighting demand to heavy tramway or industrial demands. The perfection with which one demand plays into another is also upset by factories working overtime or by cases in which, owing to special processes of manufacture, current is needed continuously all day and perhaps all night as well. But these exceptions do not seriously disturb the general rule that when a station supplies the industrial load as well as the

lighting and tramway loads it enjoys a more regular and constant output.

In the accompanying illustration (see below) we have a graphic proof of the effect of adding the industrial load to a station which otherwise supplies only the demand for electric light. The thin line represents the course of the lighting load, with its sharp peak between the hours of 6 p.m. and 10 p.m. The black line represents the factory load, which begins at

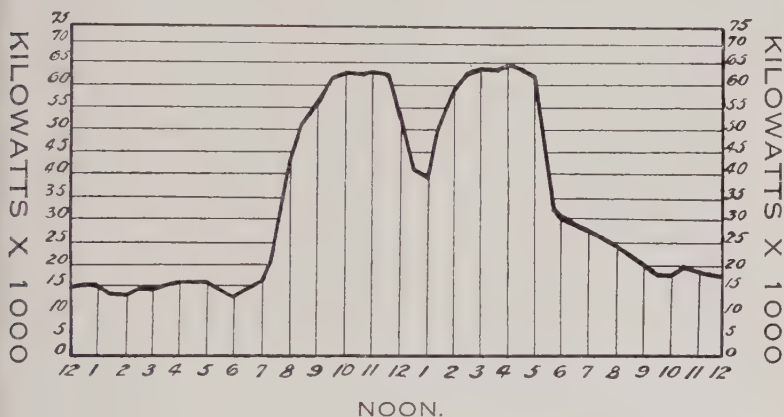


Showing how the demand for electricity for power purposes (represented by a thick black line) fills up the low portion of the curve representing the course of the daily demand for lighting purposes, thus tending to equalise the output of the generating station. (From a paper read by Councillor Panton, of Bolton, at a Convention of the Incorporated Municipal Electrical Association.)

6 a.m. and continues, with a marked drop during the breakfast hour, till noon, when it sinks to practically nothing. The afternoon demand comes on after 1 p.m. and remains heavy until nearly 5 p.m.

This curve really gives a picture of the industrial life of the city. To-day it has some historical interest, because it belongs to the year 1903 and shows that the operatives in those days began work earlier and kept at it longer than they do at the

present time. It has a further interest, inasmuch as it illustrates the beginning of the electric power business. Even at its height the demand for electric power does not reach to one half the demand for electric light. The little hills of electric power demand were destined to grow, as factory after factory took current from the central source, until the lighting peak ceased to tower so high above the electrical landscape. Another illustration shows how complete the transformation may become with the growth of power. It represents the "daily load curve" in Glasgow during 1920. No current for tramway purposes is supplied from the station in question; therefore

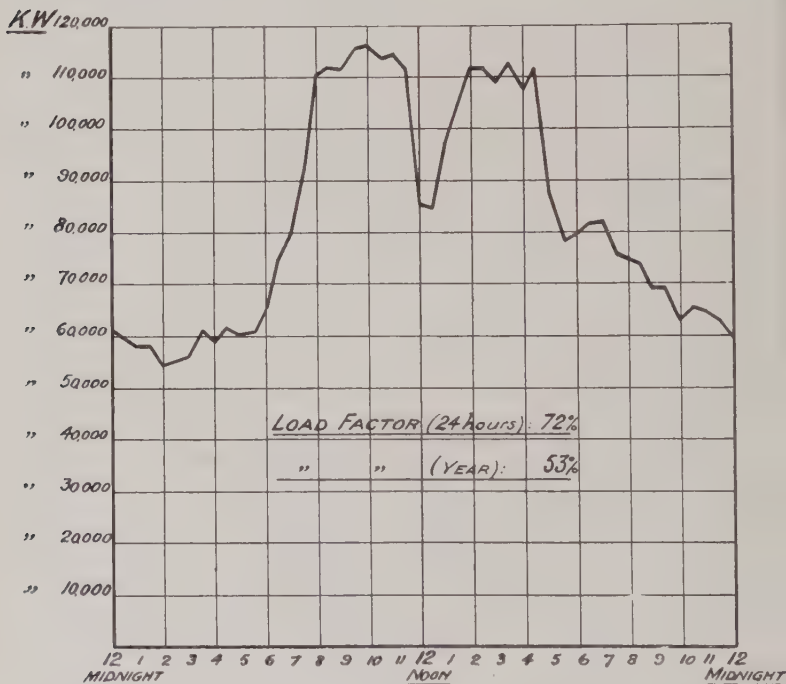


Daily load curve in the Dalmarnock Power Station of the Glasgow Corporation, showing the combination of lighting and industrial power business.

the curve indicates lighting and power only. The lighting peak has completely disappeared, and instead of it we have two plateaux, one for the morning power load and the other for the afternoon power load.

A third load curve (p. 90) reveals the effect of adding the traction load to the other two. The electrical landscape remains hilly, it is true, but the outlines are fuller, representing a more continuous output of current. When we contrast the simple lighting curve with the combined lighting, tramway, and industrial curve, we can understand why the development has been accompanied by a cheapening of electric current. Not

only is more current produced, but its production is spread over the greater part of the day, thus affording a much more profitable output from the generating plant installed. The third curve marks a closer approach to the straight line or plateau which represents the ideal of efficiency and economy in the production of electricity.



Curve showing the effect of combining the demands for industrial power for traction and for lighting on one electricity generating station. The demand during the night comes largely from electro-chemical industries.

Bound up with this improvement in the character of the demand there is a tremendous increase in its volume. The lighting peak in the first curve just mentioned (p. 88), although it is as prominent as an Eiffel Tower on a desert, represents only a fraction of the combined demands shown on the second and third curves (pp. 89 and 90). Taking the first curve as a token of what electricity supply was nearly twenty

years ago, the other curves provide a measure of its subsequent growth. The contrast in size is almost laughable ; it is like the contrast between the largest battleship or liner of to-day with the first steamships which managed to cross the Atlantic. Any of the little generating stations which were opened with so much enthusiasm and ceremony in the early days of the electrical industry could be hidden away in a corner of the huge stations of to-day. And electrical engineers are looking forward to building still larger ones.

The evolution of this branch of electrical enterprise has thus been from small stations supplying current for lighting purposes to large stations supplying current for all purposes. "Electricity supply" takes the place of "electric light." Many companies retain their old names as electric light companies, and municipal committees in control of electricity supply undertakings are still spoken of as electric light committees ; but these titles are a survival of days that are gone. Electric light, in fact, has become one of the smallest parts of the business of a modern electricity supply station.

In proving the advantage of a central station for a group of factories we touched on several of the economies of producing electricity on a large scale. One important economy was, however, not mentioned. It concerns the use of large engines.

An engine of 200 horse-power costs less than twice as much as two engines of 100 horse-power each. Also, it occupies less space and requires less expenditure in time and money on repairs and maintenance than the two smaller engines. Consequently we find that as the demand for electricity increased, the size of the engines installed to meet it grew likewise. There was, however, a limit to the benefits of size in the high-speed steam engines suited to the generation of electricity. When something like 700 horse-power had been attained, designers were met with difficulties which induced them to call a halt.

An advance was then made along another route, by using large slow-speed engines. They were the giants of those days, and were made up to about 4000 horse-power for use in the largest stations. Twenty years ago they were on the point of becoming standard practice for the leading installations, sharing the central station field with the high-speed engine of

smaller capacity. But the outlook was swiftly changed by the appearance of the steam turbine.

This invention, which we owe chiefly to Sir Charles Parsons, marked a new era in electrical history. To it we owe the possibility of producing electricity on a much larger scale and much more cheaply than would ever have been done with steam engines of the older type. In place of reciprocating action, due to the pressure of steam alternately on one side and the other of a piston, the turbine gives rotary motion by the impinging of steam upon curved blades set on the rim of a disc. The turbine shaft carries a series of rotating discs separated by fixed blades which deflect the steam in its passage from one set of rotating blades to the next. By this arrangement the energy of the expanding steam is translated directly into rotation at a high speed. The higher the speed the more efficient the translation; and, as electric generators are also efficiently run at high speeds, the use of the turbine in electric supply stations was one of the first applications to be exploited.

Again, the steam turbine is more efficient in large units than in small, and the escape it offered from the size-limitations of the steam engine was eagerly welcomed. When we speak of size, we really mean its capacity in horse-power, because the steam turbine had the most valuable advantage of taking up much less space than a steam engine of equivalent power. In some central stations one may come across a steam turbine occupying a modest corner behind an imposing row of engine-driven generating sets. In size the turbine looks a "mere nothing," yet it is probably doing all the work of the station and is able to produce more electricity than all the other plant working together.

Early in the development of the steam turbine, generating sets of about 1300 horse-power were looked upon as big and bold. Ten years ago, however, sets of 4000 and 5000 horse-power had become quite familiar; and to-day engineers are speaking of sets up to 70,000 horse-power.

Every increase in size, it must be remembered, has been sought, not for the sake of pride in mammoth generators, but in order to produce larger and larger quantities of electricity at an increasingly cheap rate. The old puzzle of whether the

chicken created the egg or the egg the chicken finds a parallel in the problem whether the central station created the demand for cheap and abundant electricity or vice versa. There has been a very close reciprocity between supply and demand. When electricity came to be used for many purposes the demand increased in quantity and also improved in quality ;

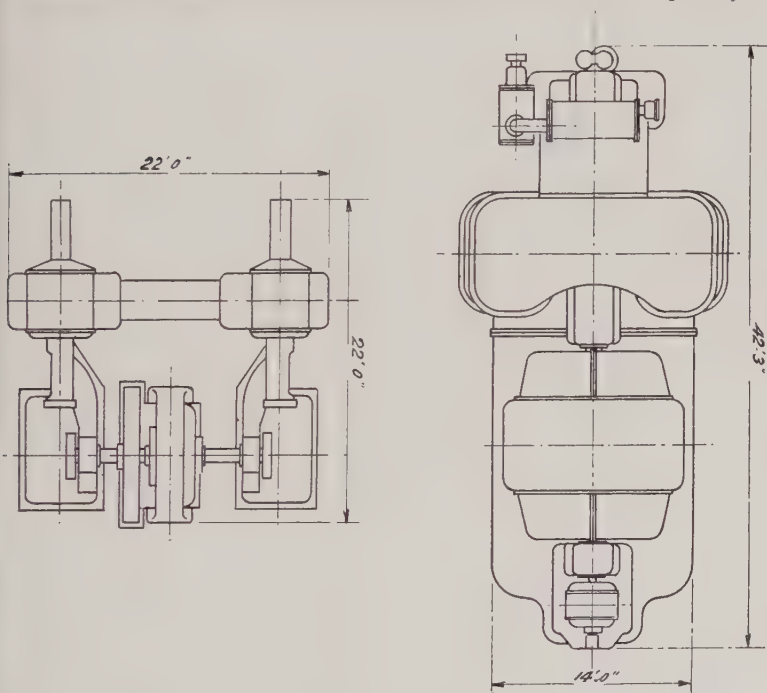


Diagram showing the comparative sizes of a 300 kilowatt reciprocating steam engine generating set and a 30,000 kilowatt turbine-driven generator. Although the turbine set is capable of producing one hundred times as much electrical energy, it occupies very little more floor space than the older machine.

the central stations, on their side, in meeting this demand, generated current under conditions more and more favourable to cheapness. Cheapness, in its turn, encouraged a larger use of electricity and so enlarged the growth of the central station. Thus, by a subtle action and reaction, progress advanced to a point at which all the electric power production for a large city could be concentrated at a single station where every refinement

of economy could be brought into operation. To this station coal is brought "in bulk" by river, canal, or rail, there to be converted in the most efficient way to electricity. From this station radiate in every direction electric mains to factories, offices, houses, and tramway systems, there to be converted to mechanical power or light or heat at the touch of a switch.

Looking back on the modest little electric light stations of forty years ago, such a gigantic centralisation of power production might well appear as the summit of the electrical engineer's ambitions. But as far back as twenty years ago many prophetic engineers realised that it was only a step towards a greater synthesis. They foresaw the time when these central stations would cease to be isolated from each other but would be linked together for mutual aid and would draw supplies of electricity from huge "super-stations." That is the phase of progress upon which we have now entered.

CHAPTER VII

THE COMING OF THE SUPER-STATION

IN 1898 a Private Bill was brought before Parliament to authorise the supply of electricity over an area of about two thousand square miles from a central station at Workop. Local authorities and companies already supplying current from their own stations were to be treated as retailers of electricity ; they were to buy current wholesale or “ in bulk,” as the phrase goes, and distribute it to their consumers. Towns without electricity were to look to the central station for supply, and individual consumers, such as factories, mills, and mines, were likewise to draw their energy from one (relatively) colossal source—the first super-station.

This Bill died an early death, but it lives in electrical history as a portent. During the same year three of the London electricity supply companies wanted to break through their parochial boundaries and build large stations for supply in bulk. Faced with these novel schemes, Parliament followed the orthodox plan of referring them to a Joint Committee which—contrary to the orthodox plan—showed itself progressive. In a lengthy report it laid down the main principle on which the industry has since progressed :

Where sufficient public advantage is shown, powers may be given for the supply of electrical energy over an area including districts of numerous local authorities and involving plant of exceptional dimensions and high voltage.

A word of explanation may be given here about the stress laid upon “ high voltage.” Electrical pressure is measured in *volts*, the unit of pressure being named after Volta, who

invented the "voltaic pile," which was the first chemical battery for producing current. Electricity must be generated at a certain pressure or electromotive force in order to flow along a wire, just as water must be under pressure before it will flow through a pipe. This analogy helps us to understand the importance of high voltage in transmitting electrical energy in large quantities over long distances. If we want to convey a certain amount of hydraulic energy from one point to another, we can do so either in a large pipe at a low pressure or in a small pipe at a high pressure. Similarly with electrical energy, if we want to transmit a certain amount we can do it either in a large cable at a low pressure or in a small cable at a high pressure. The small cable requires less copper, and it has other qualities of economy and efficiency.

Thus we find that engineers have sought higher and yet higher pressures in their power distribution schemes. While the voltage on electrical circuits in houses is usually about 200 to 240, the pressure used on tramway or suburban electric railway systems is anything from 400 to 600 volts, and it is increased to the order of 3000 volts on longer electric railways between towns. For electric power transmission "in bulk" from large stations, underground cables at 20,000 volts are used, and there is no difficulty about making cables to carry 60,000 volts. Where longer distances across open country have to be traversed, bare copper or aluminium wires carried on poles are employed, and in such cases pressures as high as 140,000 volts have been attained. A pressure of even 200,000 volts has been proposed. It is an impressive thought that many thousands of horse-power may be conveyed in an insulated underground cable no thicker than a man's wrist, and that a bare wire one-eighth of a square inch in section will carry more than 12,000 horse-power at 100,000 volts.

High voltages therefore mean economy in conveying power to a distance. They reduce the cost of the transmission line and minimise the loss of energy on the way. At the same time they involve the use of an appliance to raise or to lower the pressure as required. It is not feasible to generate current directly at the high voltages which are best for transmission, nor is it possible for consumers to use such pressures on their premises.



HOW ELECTRIC POWER IS CONVEYED BY MEANS OF OVERHEAD WIRES

The deep valley is traversed by a single span about one-third of a mile long. The wires form a main transmission line from a power station to large industrial users, and carry about a thousand horse-power.

Very large electric motors may be designed to take from 2000 to 10,000 volts, but the majority of those in factories are built for something between 400 and 600 volts. Electric lamps, cooking and heating apparatus, and other domestic electrical appliances are rated at 100 or 200 to 240 volts. To meet these conditions the electric transformer was designed. It is similar in principle to the familiar induction coil, which is supplied with current at a low pressure and delivers it at a high pressure. When used to raise the pressure a transformer is called a "step-up" transformer, and conversely it is called a "step-down" transformer when it lowers the pressure.

These particulars will serve to show how it is possible to deliver electrical energy, cheaply and conveniently, ten or fifty or a hundred miles away from its source. They also show that the impulse to carry a supply of electricity far beyond the boundary of a single town came from a study of scientific laws. While legislators were still speaking in parishes, electrical engineers had begun to speak in counties. In fact it took the legislators about twenty years to learn the new electrical language.

As far back as 1890 Mr. Ferranti proposed to transmit electricity from a power station at Deptford to the heart of London through an underground cable at 10,000 volts. Colleagues with more years of experience but much less vision declared that it could not be done; and there was some excuse for their unbelief, since everything connected with electric power transmission was so elementary that Mr. Ferranti had actually to make the cables for his great experiment. These cables were of a novel type, the insulation being provided by paper soaked in the waxy residue of candle manufacture. Not only, however, was success achieved—to the confusion of the croakers—but the cables were so well and truly made and laid that some portions of them are still at work. By a touch of real originality and courage Mr. Ferranti proved that the long-distance transmission of electricity was quite feasible; and by that triumph he laid the foundation of the big electric power schemes which the Joint Committee of 1898 foreshadowed in its recommendation about "the supply of electrical energy over an area including districts of numerous

local authorities and involving plant of exceptional dimensions and high voltage."

Several years passed, however, before these schemes came into being. They were years of violent opposition in Parliament and of pioneering work under great difficulty. When electric power companies sought the right to supply electricity "in bulk" and to factories, mines, and all other power users in entire counties, the existing supply undertakings were up in arms and declared that they would have no poaching on their preserves. The companies were denounced as piratical monopolies, out to ruin the public electricity enterprises built up by local authorities. There is no need to fight these ancient battles over again, since their dust has long settled over the graves of the arguments used on both sides, but it is necessary to note how they depressed and delayed electrical progress. Cities, towns, and even villages were cut out of the areas over which the power companies could supply electricity. Thus the fat parts of the business were left in isolation, and only the lean parts granted to the pioneers of electricity supply from large central stations over wide districts. The pioneers had to face the dilemma that they could not supply electricity cheaply until they had secured a big demand, and they could not secure that demand without offering current at a cheap rate. This meant, in effect, that they had to live on their capital through a long, arduous period of construction and development.

In the end, however, they justified themselves. They proved that the future lay with electrical production on the large scale. They proved that the old idea of "one parish, one generating station" was an engineering absurdity, that every source of supply ought to be free to extend north, south, east, and west, in defiance of local government boundaries, that the generating stations in neighbouring towns ought to be linked together for mutual aid, and that groups of towns should combine in erecting huge super-stations to supply all of them on the most economical terms. They broadened the electrical outlook from the city to the county and beyond even the county until the problem to be solved was the provision of cheap and abundant electricity to the nation as a whole.

We have to thank the War for having brought this problem within the range of practical politics. Time and again the attempt had been made to break the narrow mould in which electricity supply had been cast and to refashion it according to the broader policy, but time and again vested interests proved too strong. In the pigeon-holes of the Board of Trade there are the drafts of many Bills which were to confer upon the electrical industry its long-deferred charter, its warrant of release from the tyranny of the parish pump. Before the War, those who looked forward to freedom of enterprise in electricity supply had almost abandoned hope. The War, however, brought two new allies. On the one hand, the need for multiplying the output of munitions of all sorts led to an unlimited demand for electricity. As we have already noted, ninety-five out of every hundred of the new munition factories were electrically driven, and within four years the output of the public electricity stations was doubled to meet the needs of these new factories and of the older ones which turned feverishly to electricity as the one means by which they could produce the largest quantities of machinery and appliances in the shortest space of time. So the Government and the public had it forced upon them that electricity was a key industry of the most vital importance to an industrial nation.

On the other hand, the War had a most useful effect in broadening the mind. Local interests, parochial prejudices, and all the traditional jealousies which had formerly stood in the way of co-operation, became so petty that people were glad to forget them. A new desire sprang up to ring out the old and ring in the new in electricity supply, for the general benefit. On its matter of fact side this liberal tendency was aided by the action of the Ministry of Munitions, which took over the supreme control of electrical production. In granting permission for the extension of electricity supply stations or the erection of new stations, the Ministry had no concern with vested interests; it sought to provide the largest supply of electricity in the readiest and most efficient manner. Thus, in its autocratic way, it broke down barriers and forced neighbours into partnership. Towns which had previously considered it beneath their dignity to take electricity in bulk from

outside sources, rather than generate it in their own stations, found themselves acquiescing—in most cases with admirable grace—in the broader policy.

Thus the way was cleared for the Electricity (Supply) Act, 1919—a measure which really demands the hackneyed journalistic phrase of “marking a new era.” It also marked, to every electrical engineer’s relief, the end of the Electric Lighting Acts of 1882 and 1888, with their narrow-mindedness, their obstructiveness, and all their anti-progressive qualities. For the first time in British electrical history the supervision of electricity supply was put in the hands of experts with a reasonable measure of both freedom and responsibility.

The Act provided for the appointment of five Electricity Commissioners—three of whom were to be selected for practical, commercial, and scientific knowledge, and wide business experience, including that of electricity supply. These Commissioners were to consider and decide upon all electricity supply schemes. Chief among their first duties was to arrange for the division of the country into convenient “electricity districts”—convenient, that is to say, for electrical purposes and not bearing any necessary relation to local Government areas. In each of these districts there was to be formed a Joint Electricity Authority, composed of representatives of all the electricity supply authorities, of local authorities, of railway companies, and other large users of electricity, and of labour interests. On this Joint Electricity Authority was thrown the burden of preparing a scheme which would provide a cheap and abundant supply throughout the district, and of carrying out the scheme after it had been approved by the Commissioners.

The atmosphere created by this Act was totally different from that persisting under the earlier Acts. Instead of each electrical undertaking being encouraged to keep itself to itself, there was a powerful incentive for neighbouring undertakings to link up with each other and to combine in building large super-stations where a new source of supply was deemed necessary. All the best engineering and administrative brains in each district were pooled for the purpose of discovering and pursuing the best path of electrical progress. And the

enterprise of all the districts was fostered by expert Commissioners who looked at the question of electricity supply from the national standpoint and were anxious to "get the thing done."

There were, of course, some darker shades in this picture of a new electrical world. The cult of the parish pump still had here and there its faithful devotees, who put forward their own limited view of the "public interest"—the old Adam of obstructiveness and jealousy was occasionally resurgent. Greatest of all was the difficulty of finance. The Electricity (Supply) Act, 1919, came into force at a time when capital was scarce and costly, when electrical plant was anything from two to three times dearer than it had been before the War, and when labour and other troubles made the commercial outlook very uncertain. A sum of £20,000,000 provided by the Act out of Treasury funds helped to tide over the period while the electricity districts were being delimited and the Joint Electricity Authorities formed, but it left untouched the problem of how these large composite bodies could raise money for ambitious electrical schemes. Later the Electricity Commissioners brought in a supplementary Electricity Bill to enable electricity supply authorities to give various forms of financial support to the Joint Electricity Authorities. By this means, and by others which need not be detailed here, efforts were made to overcome the financial difficulty.

What concerns us for the moment, and from the standpoint of the all-electric age, is to sketch the lines on which the supply of electricity will progress, now that the electrical Magna Charta has been granted. The ultimate end in view is that cheap and abundant electricity shall be available in every part of the country—not simply in cities and towns.

The first step to be taken is for each existing centre of supply to extend its mains further afield. In the old days there was quite a fuss when a supply undertaking wanted to cross a local boundary, but to-day a Joint Electricity Authority can easily arrange for an undertaking to run electric mains, overhead or underground, to outlying villages and to farms, houses, and such industrial centres as quarries, brickfields, and saw-mills which lie between the villages. An excellent

example of this kind of extended supply is afforded at Hereford, where overhead lines run for as many as sixteen miles from the city into open country.

Further opportunities for giving a supply to hitherto neglected areas occur in connection with the electrical linking-up of towns within a few miles of each other. The advantages of this linking-up have already been explained ; they are so great and so numerous that interlinking forms one of the chief items in the programme of Joint Electricity Authorities. Each trunk main which couples up two generating stations does more than enable one station to supply the other as required. It forms a river of electricity which can be tapped at any point to supply any kind of electrical demand, large or small. The country lying between two towns can thus be irrigated with electric power.

These two forms of extended supply are supplemented by the enterprise of the electric power companies, which were formed to range far and wide to pick up scattered demands for electricity. Coal and iron mines, quarries, waterworks, textile and other mills, and other industrial enterprises are often situated outside the boundaries of cities and towns, and they can be reached from a central supply only by a network of mains which traverse many miles of comparatively open land. Each of these mains, again, can have its branch mains to meet the demands of farms, houses, and other incidental users of electricity, or it can supply "in bulk" to towns or villages which do not possess stations of their own. If we represent the electric power company as a kind of free-lance of electricity supply we gain a fairly accurate notion of the part which it plays in making the provision of electricity universal. Whether a virgin area will be electrically developed from a neighbouring town or by a power company is a question which a Joint Electricity Authority will decide, according to the local conditions.

Still another means exists for carrying electricity far afield. The Electricity Commissioners are attached to the Ministry of Transport, and although this arrangement was resented in some electrical quarters it is not without justification. Part of the programme of the Ministry of Transport is the electrifica-

tion of main line railways for both goods and passenger traffic. Before this revolution can be carried out an ample supply of cheap electric power must be made available at various points along the routes of the railways. The Ministry is therefore anxious that the organisation of electricity supply should be arranged with this necessity in view. When, for example, a Joint Electricity Authority considers that a super-station should be built to supply electricity wholesale over a large part of an "electricity area," the position, size, and design of the station should, if possible, be suited for the provision of electric power to the railways in or adjacent to the area.

The advantages of combining the main line railway load with the industrial and general loads are similar to those of adding the tramway load to the others obtainable in town. But the development of electrification over scores of miles of railway brings an additional advantage for a Joint Electricity Authority. The electric mains laid alongside a railway to carry electricity to the trains form, like the trunk mains between inter-connected towns, "rivers of power" from which the neighbouring country can be irrigated. Towns and villages near the railway are thus provided with a cheap and abundant source of electricity; isolated rural industries can also tap this source by means of an overhead main; and the railway becomes the supplier of light, heat, and power as well as of transport.

A short study of the map of Great Britain will show that by these four methods—the extension of mains from towns, the branching of trunk mains connecting towns, the spreading of the network of electric power companies' mains, and the tapping of the rivers of power flowing along the electrified railways—electricity supply will spread itself over the greater part of the country. The thirteen electricity areas first delimited by the Electricity Commissioners are those in which the greatest need and the greatest prospect exist for the wider spinning of the electrical web. Nevertheless, even within these areas there must remain many secluded districts, with a scattered population and few industries other than agriculture, into which electric mains will not penetrate for many years. As for the parts of the country not yet delimited as electricity

areas, they are mainly what the electrical engineer regards as "lean." Small towns at wide intervals; villages scattered promiscuously; a general prevalence of fields and moors and forests: these are conditions which offer little demand for electricity and therefore little chance of providing electricity on a paying basis. On the other hand, remote and modest centres of population may desire electricity as much as, if not more than, towns and villages which have the advantage of being close to the nerve centres of civilisation. So it is worth while considering whether this part of the electrical problem has any promise of a solution.

In describing electrical generating plant we referred only to dynamos driven by steam. Of late years, however, there has been a large development of the oil engine for the generating sets of a hundred or two horse-power suitable for supplying a small town. These installations fill the gap between the little plants, running on petrol or paraffin, which supply electricity for country house lighting, and the steam installations with reciprocating engines or turbines. They have been handicapped by the high cost of the engine and of oil fuel, and also by certain operating difficulties; but there is every prospect that they will become more and more economical sources of electric power as time goes on. Any small community which can gather together an electrical demand of a reasonable size and variety can meet it economically enough by a co-operative installation, using the oil engine and simple overhead transmission.

There is, however, another source of power which Arden may utilise. The remote parts of the country are precisely those in which water power abounds. Apart from the highlands of Wales or Scotland, the power available is seldom large, but to some extent it makes up in frequency for what it lacks in magnitude. Scattered over the rural parts of England there are hundreds upon hundreds of small water mills, many of them derelict but many others still grinding corn or sawing wood. They are nearly all survivals of the days before steam, when the fall of water was, with the horse, the only useful substitute for manual labour. The dams and machinery

associated with them are very primitive and therefore capable of great improvement. In some cases, by enlarging the dam of an old mill and installing up-to-date water turbines to drive dynamos, enough electricity has been obtained to provide light, heat, and power for an extensive estate.

Any landowner who sets out to develop water power on his estate for electrical purposes will soon discover the fallacy of the popular notion that waterfalls or streams produce electricity "for nothing." The civil engineering work involved in building or enlarging a dam and constructing pipe lines or channels for the water is costly; and the expense of erecting and equipping the electrical plant is no small item. Against the fact that no coal or other fuel has to be bought there are the interest and other capital charges on the initial expenditure. Another point which must be kept in mind is the unreliability of the supply. A period of drought may lead to an empty dam, and a prolonged, severe frost may seriously interfere with the operation of the plant. The moral of these facts is that both a liberal purse and skilled advice are necessary before a water power can be put to successful use. Under favourable conditions, nevertheless, profitable use can be made of wayside water powers.

The Water Power Resources Committee formed by the Board of Trade has been engaged in surveying the field for hydro-electric development in Great Britain. It estimates that a total of about one million horse-power may be obtained from this source. As already indicated, the largest water powers are in regions remote from industrial centres. If these large powers are exploited, we must either take the industries to the waterfalls or we must transmit the power in the form of electricity to distant towns. Owing to the heavy cost of the civil engineering work, it is an open question whether, for example, a hydro-electric plant in the Highlands of Scotland could supply electricity to other parts cheaper than it could be generated there from coal. North Wales offers a better opportunity, because there are slate-quarries and other power-using industries in the water-power district and because there are crowded centres of population at no great distance. A scheme is already on foot for developing the hydro-electric resources

of North Wales on these lines. But the enterprise of the British Aluminium Company, Limited, represents the more promising method of utilising our large water powers. The manufacture of aluminium requires a constant supply of large quantities of electricity at the cheapest possible rate ; and this demand is readily met, under the appropriate conditions, by a hydro-electric installation. The works of the Company at Foyers utilise electricity obtained by damming the adjacent valleys ; and their raw material—chiefly clay—is transported economically by sea. This is a typical example of the cases where it pays to carry the industry to the waterfall.

A less striking but by no means unimportant way of using hydro-electric power is in conjunction with supply from steam-using stations. At Chester the damming of the Dee provides a low head of water which is used for hydro-electric plant of 720 horse-power. The fullest possible use is made of this plant, and the steam station is drawn upon to supply the additional power required when the demand exceeds the capacity of the hydro-electric installation. This combination has proved so economical that plans for raising the level of the river and obtaining still more water power have been evolved. Worcester provides a similar example, and there are probably other places in England where a moderate fall of water in a river of good volume may be harnessed with advantage. If, as may be confidently expected, the network of electric mains from steam-driven stations extends until it covers the greater part of the country, we may find many a quietly flowing river adding its quota to the current flowing through the network.

Last, or at least last of all the great sources of power, comes the tide. Public imagination has long been stirred with the thought of harnessing “ moon power ” by utilising the tremendous energy represented in the eternal rise and fall of the sea waters. In estuaries like those of the Severn the waters pile themselves up as they flow into a narrowing channel ; and the economic soul of man is depressed by the spectacle of such colossal forces going to waste. This economic soul is, however, still more depressed by the estimates of what it would cost to

turn these forces to account. The civil engineering work involved in the dams and sluices and other structures needed to control the tides in an estuary is formidable. And the problem of getting a continuous supply of electricity from a source which ebbs and flows twice daily and alters its range according to the phases of the moon is full of difficulty.

Nevertheless, the Water Power Resources Committee went very deeply into the question of utilising tidal power, and was so favourably impressed with a Severn scheme put forward by three engineers—Mr. Meik, Mr. Addenbrooke, and Mr. Twinberrow—that it recommended the appointment of an expert committee to go further into the matter and work out detailed estimates. The Ministry of Transport later published a similar scheme on its own behalf, but, although it spoke of obtaining half a million horse-power and producing current at one halfpenny per unit, it did not venture to give any hint as to the probable cost of the scheme.

The proposal in both cases is to construct a barrage across the Severn close to the route of the Severn Tunnel and to use this barrage as a foundation for a railway and a roadway as well as for the purpose of damming back the water raised by the tidal flow. In order to provide an equalising reservoir of power, the excess of energy at spring tides is to be used to pump water through a tunnel to a high-level lake in the adjacent hills.

The Water Power Resources Committee takes the view that such a project is, as a matter of engineering, feasible enough, but that the most detailed survey of the physical conditions and the closest study of all the novel technical points involved are necessary before any beginning can be safely attempted. It suggests a trial installation on a smaller scale in some more modest estuary before anything so gigantic as a Severn barrage is contemplated. Had it not been for the great increase in the cost of coal during recent years it is probable that nothing would have been heard of such schemes. Nor, indeed, would there have been so much inducement to study the use of water power in any form. The whole basis of comparison between steam and water power has been altered by the advance in coal prices ; and more thought is being given to

conserving a wasting asset such as coal by erecting permanent works to obtain power from the "perpetual motion" of rivers and seas. In the main, however, it is through coal that Great Britain will realise the all-electric age.

There is another form of natural energy which electrical engineers have considered from time to time as an economical source of electricity. Wind-mills, like water-wheels, are ancient machines, and they are still largely used for pumping water, for grinding corn, and for other processes where wide variations of power and frequent stoppages do not matter very much. Attempts have often been made to devise some means of getting a constant supply of current from a source which is as inconstant as woman—in the cynic's opinion. The usual plan has been to employ a battery in which the electricity produced by strong winds is stored up for periods of calm; but even with a large battery one week of halycon weather will exhaust the store. Nevertheless, the windmill should not be dismissed as hopeless for electrical purposes. Hitherto the difficulty has been that the windmills and the generators do not make use of the lighter winds which, in certain situations, can generally be relied upon to fill the gaps between strong winds and gales. By means of an improved wind motor and a special form of generator every zephyr can contribute a little to the store of electricity. In remote hilly districts, where a moderate amount of power is required, there should be opportunities for developing wind-power installations on an economical basis.

All the sources of electricity so far utilised are derived from the sun, more or less indirectly. This fact has led men of science to think over the problem of using in a more direct way the flood of energy which the sun is continually pouring upon the earth. The "solar engines," of which there are one or two examples in tropical countries, represent the simplest solution. They consist of a series of metal reflectors arranged to concentrate heat on a boiler generating low-pressure steam which is used to drive an engine. A rather elaborate equipment is, however, required to produce a very small amount of power; and the solar engine is perhaps more of a curiosity than a commercial proposition.

Meanwhile the scientific imagination is more attracted by the possibilities of producing electricity direct from sunlight. When light falls on a particular kind of "cell," currents of electricity are produced. So far only minute currents have been obtained, but the fact that they are generated is a kind of prophetic glimmer in the darkness of scientific speculation. It suggests that we are approaching the dawn of great discoveries. Light and electricity are, in essence, closely related; and in the future we may get our electric power straightway from the radiations of the sun instead of on the roundabout method of burning vegetable matter built up cell by cell in past years by those same radiations.

A still deeper speculation suggests that power may be obtained direct from matter. The atoms of which all substances are composed were once regarded as particles which could not be divided—the ultimate bricks out of which the universe had been built up. It is now known that every atom is a complex system—a kind of solar system in miniature—of whirling particles of electricity called "electrons." These electrons are almost inconceivably minute, but, as Mr. Llewelyn Atkinson (President of the Electrical Engineers, 1920-21) once remarked, we know more about them than people know about their own boots. Their diameter has been calculated at about one hundred-thousandth of that of the smallest atom.

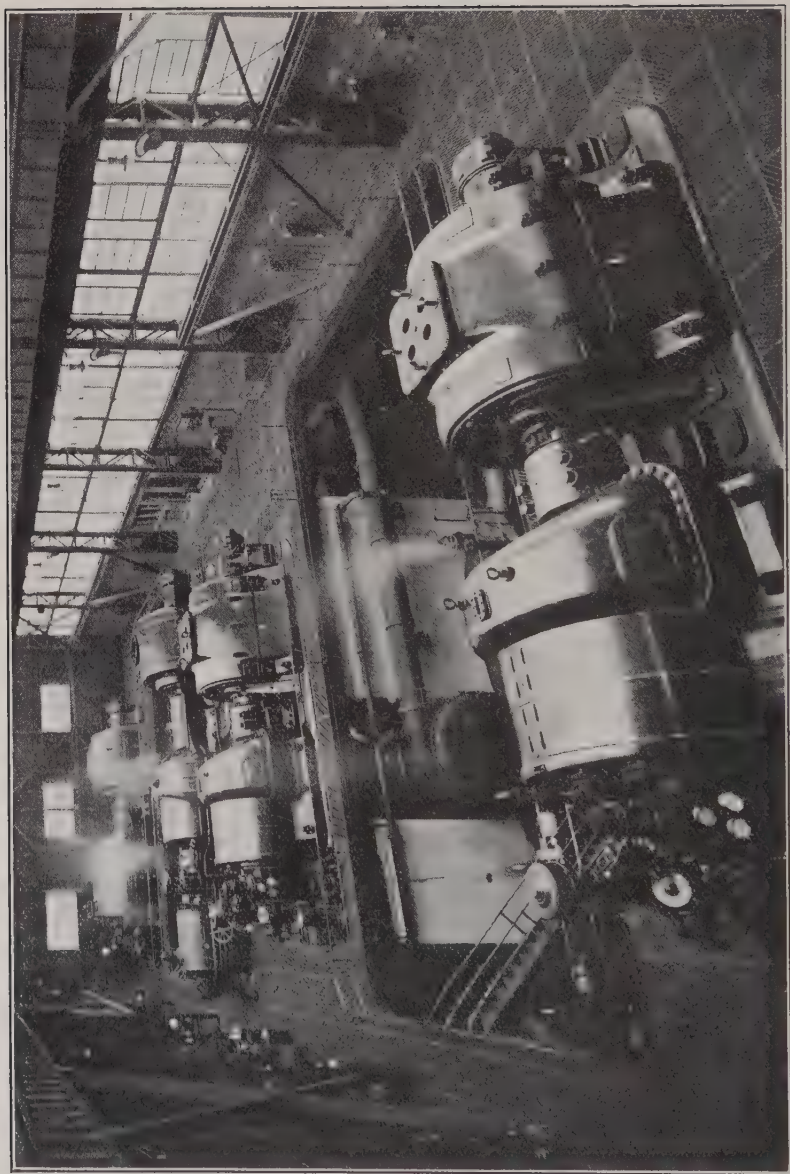
They, and not the atoms, appear to be the ultimate bricks. In the case of radium and other "radio-active" bodies we see the systems of electrons breaking up, throwing off streams of particles and, in a word, radiating energy. These discoveries have given us a new sense of the marvels of matter, and they have also suggested that if we could somehow or other unlock the energy of the atom we could tap unlimited sources of power. If ever this triumph is achieved, all our power stations and transmission mains, and so on, may become obsolete, and our coal-mines and oil-fields will become deserted.

These speculations are, however, very much in the air or, rather, in the ether. For a long time we shall almost certainly have to rely, as already stated, upon the reserves of coal for

the cheap and abundant electricity needed to drive our factories and vehicles, to light and heat our homes, and to cook our food. The next stage in the evolution of electricity supply is the erection in various parts of the country of those large electric power stations which are called super-stations because they will supply electricity wholesale to stations already producing electricity on a large scale. In those super-stations the largest turbine-driven generators will be installed, and every part of the mechanical and electrical equipment will embody the latest refinements which lead to economy and reliability in the production of electricity.

There is a prevalent notion that the proper place for these great centres of cheap electricity is the pit's mouth, where coal is obtainable at the lowest price. But in large stations, where enormous quantities of steam are used, there is one item which is just as important as cheap coal, and that is an ample supply of water for condensing purposes. Nothing short of a river or a lake is adequate for a super-station, and therefore the choice of site is more restricted than is usually realised. Another condition to be fulfilled is that the station shall be reasonably close to the places it supplies; long transmission mains are an added expense. Great technical skill is, in fact, needed in arranging the location as well as the equipment of these mammoth sources of power.

In its broadest outlines the electrical picture for the immediate future shows a limited number of super-stations pouring electricity wholesale into the network of trunk mains linking up electricity supply undertakings, each with its own system of mains radiating in all directions. The generating plant owned by these undertakings will remain at work, or as a stand-by, for many years. Step by step, however, the smaller and less efficient stations will be shut down and will become mere sub-stations or centres of distribution. One by one the smaller generating sets in the larger stations will be discarded or will fall to the rear as reserves in cases of emergency. The whole design is to concentrate the production of electricity in the larger stations, but the idea which some people once entertained that the Electricity Commissioners are bent on scrapping all the old stations and confining the generation of



INTERIOR OF A MODERN ELECTRIC POWER STATION

electricity to about sixteen super-stations is an absurdity which arose out of a misunderstanding. There may be sixteen or more "electricity districts," but each of these will have not one, but several stations. Unity will be confined to the general control of electricity supply enterprise in each district ; it will lead to the linking-up of stations and the building of super-stations, but not, for some years to come, to any drastic shutting down of existing plant.

It is important, however, to keep in mind the fact that linking up is useful only when the stations are fairly close together in an area with a good demand for electricity. Nearly all of the first thirteen electricity districts provisionally delimited by the Electricity Commissioners were largely industrial. Outside of them lay great tracts of country with widely scattered towns or broad acres given up to agriculture. In such parts the smaller isolated generating stations will certainly remain, supplemented by water power, by supplies from electric railways or by small private stations, and even by wind-driven plant.

Our object in going over these points is to lay stress on the number of methods by which, according to circumstances, the demand for cheap and abundant electricity can be met. Just as sea power is attained by the use of battleships, battle-cruisers, cruisers, torpedo-boats, coastal motor-boats, submarines, aircraft, and other means, each in its appropriate field of action, independently or in combination, so electric power is secured by super-stations, large city stations, town stations, small steam or oil plants, hydro-electric installations, and other sources of electrical energy. By various channels the electrical engineer hopes in time to irrigate the whole country with electricity, so that wherever an industry may be established or a home erected, electricity will be available to fulfil its manifold functions.

CHAPTER VIII

MODERN ELECTRIC LIGHTING

IN our second chapter a short account was given of the earliest electric incandescent lamp, which had a carbon filament, and of the electric arc lamp, in which light was produced by the flow of electricity between two pencils of carbon. For a quarter of a century and more these two forms of lamp were the pillars of the electric-lighting industry, the first for small units of light suitable in houses and interiors generally, and the second for the large units employed in lighting open spaces, factories, and public buildings. The industry was, in fact, built up on carbon.

During that period many improvements were made in both types of lamp. The carbon lamp became more efficient ; that is to say, it gave more light for the same amount of current. It was also made more reliable and more lasting. The arc lamp, too, evolved into the "flame arc." Certain salts were mixed with the carbon, and the arc was enlarged by magnetic action, the combined result being a luminous arc of the greatest brilliance. But it is significant that early inventors of carbon filament lamps scheduled in their patents a number of metals and other substances, some of them very rare. Clearly they felt that, although carbon was the most suitable element so far known, it was not going to be the best for all time.

They were right. Early in the present century the osmium incandescent lamp appeared. It was suitable only for low voltages, and it had other disadvantages which cut its career as a commercial article very short. But it was the first lamp with a filament of drawn metal wire, and as such it was a portent of great things. New types of metal lamp followed each other with almost bewildering rapidity. First on the

market was the tantalum lamp, tantalum being a metal which could be drawn into wires of almost invisible fineness yet of great strength. This was a most popular lamp, as it was at least twice as efficient as the carbon lamp. It enabled consumers to obtain double the light for the same money or to halve their electric lighting bills while enjoying the same measure of illumination.

Hard on the heels of the earliest tantalum lamps came the first lamps with filaments of the rare metal tungsten. These were not filaments of *wire*, because tungsten is obtained in the form of a fine powder, and the task of transforming a powder into a ductile ingot which could be drawn through dies into a fine wire seemed beyond the skill of any inventor. The powder was mixed with a binding material into a paste which was squirted through a diamond die; then the binding material was burned out, leaving a more or less coherent thread of tungsten particles. The first tungsten lamps were thus very fragile. Casualties on the way from the factory to the user were appalling, and, even after the lamps were safely installed, a slight jar was sufficient to break the filament. In spite of all these disabilities the lamps were eagerly bought, because they were *three times* more efficient than the most efficient carbon lamps. Gradually, as experience in making these lamps was gained, the filaments became much stronger; but no sooner had the plant for manufacture been brought to a good pitch of efficiency than it was made obsolete by the discovery of a means of actually drawing tungsten into wire.

When tungsten powder is subjected to great pressure and heated in an electric furnace the particles *cohere*. In this way slugs of the metal, about the thickness of an ordinary stick of sealing-wax, are formed; and after these slugs have been violently hammered out into a thin rod the metal is in a condition to be drawn step by step into the finest wire. Lamps made with filaments of this wire are quite as robust as carbon filament lamps; they last much longer, and, as just mentioned, they consume about one-third the amount of current, light for light.

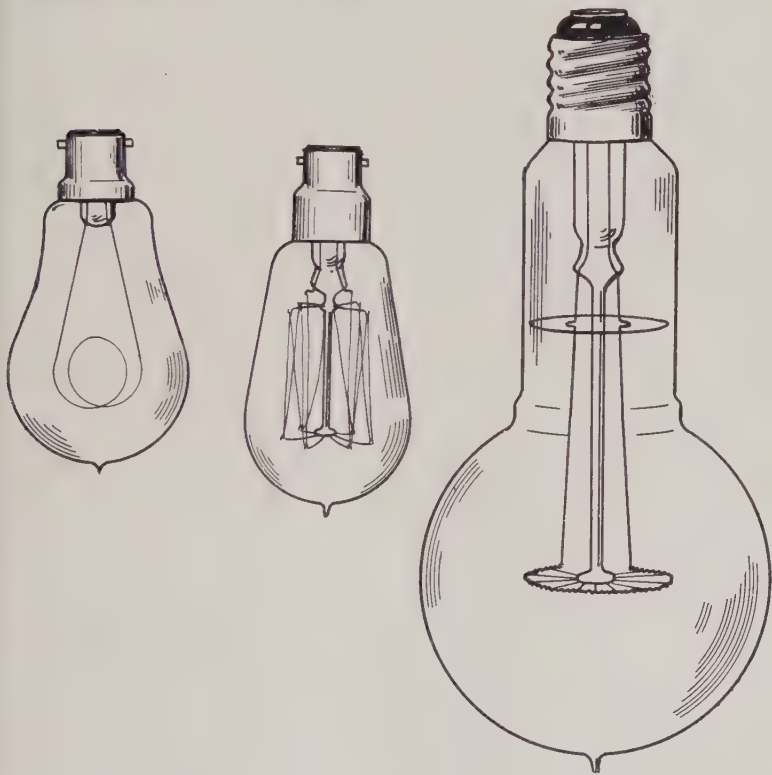
It is impossible, in a brief review of this kind, to give any proper idea of the scientific research, technical genius, and

manufacturing skill involved in the production of the present-day tungsten filament lamp. Nevertheless, the customer who buys an electric lamp over the counter may appreciate his purchase a little more if he realises that for a few shillings he obtains a scientific marvel, in achieving which many hundreds of thousands of pounds were risked and the knowledge of two hemispheres laid in tribute.

This marvel was, however, only a stage to another marvel. If we ask why the tungsten filament lamp is three times more efficient than the carbon filament lamp, the answer lies in the higher temperature at which it is run. The hotter the filament the more light it will give for the same current consumption. Many efforts were made to strengthen carbon filaments so that they could be raised to an unusually high "white heat" without crumbling away quickly; but they were only partly successful. One leading electrical engineer, in fact, used to advise "over-running" carbon lamps (that is to say, using them on circuits with too high an electric pressure) on the ground that although they gave up the ghost quicker they were so much more efficient while they held on to burning. "A short life and a merry one," was his motto for electric lamps. But when the tungsten filament came along it was found possible to have both a long and a merry life for electric lamps; and the improvement stimulated inventors to discover some means of running the filament safely at a still higher temperature than was possible in the ordinary tungsten lamp.

In this lamp, as in the carbon lamp, the filament "burns" in a vacuum. While, owing to the absence of air, it does not actually burn, it slowly disintegrates under the action of intense heat. The blackening of the bulb is a result of this process. If the pressure of the electric current is raised, the filament glows more brightly and disintegrates more quickly. It was found, however, that if a small quantity of some inert gas were introduced into the bulb, the process of decay was arrested. The pressure of the gas on the filament seems to hold it together, and the constant circulation of the gas in the bulb keeps the filament from becoming dangerously hot. Nitrogen was the first gas tried, but later argon—whose

existence in the atmosphere was discovered by the late Sir William Ramsay—was used. The filament, instead of being hung—as in the vacuum type of tungsten lamp—vertically between two sets of supports, is formed in a small close spiral



THE THREE MAIN TYPES OF ELECTRIC INCANDESCENT LAMPS

On the left is the carbon filament, which was the original type. In the centre is the tungsten filament lamp, with a vacuum bulb; this type is about three times more efficient than the carbon type. On the right is the latest type—the “gas filled” lamp, with a tungsten filament in a bulb filled with the inert gas argon—about six times more efficient than the carbon lamp.

which is arranged in a horizontal circle. A considerable length of wire is thus brought conveniently into a very small space.

Thus was born the “gas filled” tungsten lamp, which is about *six times* more efficient than the carbon lamp. Originally the gas filled lamp was called the “half-watt,” because it con-

sumed about one-half of a "watt" (the unit of electrical energy) for every candle-power it produced. Similarly, the vacuum type of tungsten lamp was sometimes called a "one-watt." (The carbon lamp, by the way, took anything from three to four watts and over per candle.) These terms have, however, been discarded as being unscientific, and it is now correct to speak of the two types of tungsten lamp as "gas-filled" and "vacuum" respectively.

While the vacuum type made the carbon lamp practically obsolete, the gasfilled type displaced the arc lamp. Gasfilled lamps were first made in large candle-powers—1000 to 2000—and they are most efficient at that range. Therefore they struck their earliest blow at the arc lamp which, though the flame arc remains the most efficient source of artificial light, had a complicated mechanism to be looked after and had to be supplied at frequent intervals with new carbons. With extraordinary rapidity the gasfilled lamp replaced the arc for lighting streets, docks, factories, halls, and large spaces in general. The arc lamp found its last refuge in its first home—the searchlight or projector—and even that retreat is not proving quite secure.

For some time, therefore, the vacuum and the gasfilled lamps occupied much the same respective territories as had been filled by the carbon filament and the arc lamps. One territory included the domestic field and others where small units of light were needed; the other included the industrial and public fields, where large units were used. But gradually—and within quite recent years—the gasfilled lamp has extended its range downwards until it has covered a goodly portion of the domestic field. During 1920 gasfilled lamps of about 100 candle-power became available for ordinary electric lighting circuits; and it is quite possible that they will go still lower until the vacuum type is almost squeezed out.

It is also possible, nay very probable, that the course of invention in electric lamps will give us something radically more efficient than even the gasfilled lamp. But, taking things at the point of actual achievement, the swiftness and the extent of the advance have been remarkable. Where else, in our recent history, can we find any commodity which by a few

strokes of invention has become six times cheaper than it used to be ? The increase in the cost of electricity, owing to the War, has of course masked the full effect of this progress, but it does not touch the fact that the appliance we use to-day for converting electricity into light is six times more efficient than it was ten or fifteen years ago. And the nation would be very thankful if, in all other directions, the higher cost of things were so wonderfully compensated.

The more we realise the greatness of this advance, the more we must appreciate the disabilities with which electric light had to contend in the early days. Electricity was then expensive ; the lamps were dear and inefficient. For many years a hot controversy raged on the question whether gas or electricity was the cheaper source of light, and although electrical engineers showed a wonderful fertility in producing comparisons in favour of electric light they did not always make the most of the real advantages of the thing they had to sell. What we have to note to-day is that electric light steadily advanced even while it had nothing better to offer than the carbon lamp. Beginning with hotels, restaurants, shops, and theatres, it gradually widened downwards through the houses of the middle classes even as far as the cottage. The cause of this progress lay in the *secondary advantages* of electric light. Taken by itself as a source of illumination, an electric lamp might not be cheaper than its rivals, but when used in a house it brought a number of benefits which made it both so desirable and so economical that more and more people came to use it.

It is worth while dwelling upon this fact, because the same thing applies to electric heating, electric cooking, and to the labour-saving uses of electricity in the home. There the secondary advantages of electricity are just as important as they are in connection with electric power in factories.

The first of the advantages of the electric lamp was that it could be easily switched on or off in a moment. Most people looked upon this facility as a mere convenience ; it was simpler to touch a switch than to strike a match (after having found one) and to light a gas jet or an oil lamp. But there was much more in it than the saving of trouble to lazy folk. When the turning

on of a light involves any bother, everybody tends to leave lights burning all the evening in passages and rooms which may be used only occasionally. This waste, going on day after day, week after week, and month after month, became a really serious item in the cost of illumination ; but when electric light was used this item was cut out altogether. Therefore, although the cost of actually lighting a room for an hour might have been greater when using electricity, the bill for electric light at the end of a quarter might well be less than the bill for gas in houses of the same size and character.

Thus the economy of electric light lay as much in the switch as in the lamp. There is, as we shall see presently, an art in switching, by which the greatest convenience and the highest economy may be secured. But if we take switching in its most elementary form, where each lamp or group of lamps is controlled by one switch, we see that it gave electric light an advantage which translated itself into hard cash.

The next advantage of electric light was that it involved no flame. A flame consumes oxygen and gives off fumes in which carbon dioxide, water vapour, and in some cases sulphur dioxide and other deleterious gases are present. In the earlier days of controversy most of the talk was about robbing the air of life-giving oxygen and filling the room with the death-dealing carbon dioxide, but experiments made in recent years suggest that an excess of carbon dioxide is not really bad for health. However that may be, users of electric light were quick to appreciate how much less stuffy their rooms were than when flames were burning in them. Electricity gained the reputation of being the healthiest light ; and as such it was sought after. But the absence of a flame in the room brought other benefits. The upward current of hot fumes from a flame carries dust with it, and it may also contain a certain amount of fine soot, the result being that it deposits dirt on the ceiling and upper part of the walls. The bad effect on decorations was increased by the moist heat of the fumes and by the sulphur dioxide. So when electric light was installed, people found that they did not need to whitewash ceilings or renew wall-papers nearly so frequently. Taken over a course of years this advantage represented a material saving

Incidentally it brought another benefit. In Victorian times the darker shades of wall-paper were most popular, because they "did not show the dirt." The dirt was there, of course, and our forefathers purchased the hypocritical appearance of cleanliness at the cost of making their homes gloomy. Dark wall-papers absorb most of the light that falls upon them ; and, as an object becomes visible only by the light it reflects, it was necessary to provide an excess of light in order to make a dark wall-paper look reasonably well illuminated. Very few people realise that it is electric light which has made light wall-papers—and therefore bright rooms—possible. With electricity even the lightest wall-papers can be kept clean for several years. They make our rooms more cheerful by day, and at night they reflect the beams of the electric lamps so efficiently that they make our domestic environment much more pleasant than of old. Here again a money value is involved. With light-tinted papers less powerful lamps are needed to give sufficient illumination, as less light is soaked up by the walls.

In hotels, restaurants, shops, and public buildings generally, where a large amount of light is required and where expensive decorations are used, these advantages were secured on a greater scale than in the home. A light which was under immediate control, which had no effect on decorations, and which enabled white paint and gilt to be used freely, brought so many savings and other benefits with it that the question of cost, light for light, sank into the background and was forgotten.

To the list of benefits we must add the reduction in fire insurance premiums. It is a curious thing that newspaper reporters, when dealing with fires of unknown origin, have a habit of attributing them to "the fusing of an electric wire." This habit is not so common as it used to be, as even the youngest reporter is now aware that very few fires are due to any electrical cause. The parrot-like repetition of the phrase has, however, given many people the notion that a special risk of fire is attached to electricity. In complete disproof of this notion we need only point to the fact that the fire insurance companies grant a reduced premium to electrically lit buildings,

The sole condition they make is that the installation shall be carried out according to certain rules.

Many years ago the Institution of Electrical Engineers drew up the regulations for the wiring of buildings for electrical service ; and these rules, which were recently revised in the light of long experience, have become standard practice throughout the country. They are designed to secure safety from shock as well as from fire, and to make electrical installations reliable in every detail. It is worth noting that these "wiring rules" were drawn up voluntarily by the industry itself. Their general adoption proves how keen the industry is to give the public a safe and certain electrical service.

The subject of switching is so fascinating that it almost demands a chapter to itself. Once its first principles are stated, however, the rest is mainly a matter of detail which perhaps appeals more to the electrical engineer than to the user of electric light.

A switch is simply a device for "making" and "breaking" an electric circuit. When we "turn on" electric light we complete the circuit which connects the lamp with the mains ; and when we turn it off we make a gap in the circuit and the current ceases to flow. The switch can be introduced into the circuit at any point, and in the ordinary domestic installation it is placed just inside of each door.

If the art of switching had never gone further than this it would still have been a boon. To be able to produce light by flicking a knob on the wall is to reduce the business of artificial illumination to its simplest terms. But it is not difficult to see how much additional convenience can be obtained by carrying things a little further. We can either control several lights from one point, or we can control one light from several points. A few examples will show how this facility leads to convenience and economy in the use of electric light.

The first electrical installations in houses were a close imitation of gas installations. Three-light electroliers took the place of three- or four-light gasaliers. For many purposes it was unnecessary to have all three lights burning. For example,

when setting the table or dusting the room in the early winter morning the full illumination would have been extravagant. Therefore it became customary to divide the circuit into two, putting one lamp on one circuit and two lamps on the other circuit, and giving each circuit a switch at the door. By this means it was easy to have one, two, or three lights at the touch of a switch or, rather, of two switches. By an additional refinement the two switches could be combined in one switch.

Again, in a large room with two doors, the lights could be controlled from switches at both doors, so that anyone passing through the room could switch on one of the lamps as he entered and switch it off as he went out. This is what is known as two-way switching, and it is of immense convenience in corridors and staircases. The best place for the switch controlling a hall lamp is, of course, just inside the front door, but this position is very awkward for the "last man" when going upstairs to bed. He must walk to the door, switch off the light, and make his way upstairs in the dark. Again, if one is called up in the night it is necessary to walk downstairs and through the hall in the dark before one can get at the switch. These inconveniences are avoided by placing a second switch on a landing to control the hall lamp.

A similar argument applies to higher flights of stairs and to corridors. Unless the lights can be switched on and off from more than one point, it is almost imperative that they should be kept burning in order to enable people to move about the house in safety. By spending a little more money on the switching arrangements, a good deal of money can be saved, year in and year out, by having the staircase and corridor lights burning only when they are actually wanted. We need hardly emphasise the advantage of these additional switch points in cases of alarm from burglary or fire. Light is a safeguard in both cases, and it is vital that it should be available instantly.

Bedrooms provide another useful field for refinements in switching. Small bedrooms usually have a lamp hung over the dressing-table and a switch just inside the door. This is convenient enough on entering the room, but it is not convenient when one is ready for bed, because it involves walking

to the door, switching off the light, and finding one's way to bed in the dark. Therefore a second switch close to the head of the bed is very useful. As the position which a bed occupies in a room depends upon the notions of the tenant, it is an additional convenience to use a "pear-switch" (so-called because of its shape) attached by flexible wire to the switch-point on the wall. The pear-switch is hung on the bed-rail, in which position it can be readily found when one awakens in the dark.

Even in the smallest bedroom, however, one light is not enough for all requirements. The lamp over the dressing-table is seldom in a suitable position for anybody who wants to read in bed or who happens to be ill. To meet the case a lamp suspended over the head of the bed or a portable lamp (either a table lamp or one which can be hung on the bed-rail) is necessary. The switches can be so arranged that either or both lamps can be alight and can be controlled from the door or from the bed. Apart from convenience, it should be noted that this arrangement makes the delightful practice of reading in bed free from objection. Doctors have condemned the habit because without electric light it is almost impossible to get illumination which will not strain the eyes. Electric lamps can be placed in any position and shaded so as to give the soft diffused yet adequate light required for reading with comfort. Candles, which are often favoured by people addicted to this practice, do not give sufficient well-diffused light, and their dangers are too well known to need discussion.

These examples will show that if we want to realise the greatest conveniences and economies of electric light we must give the art of switching full scope. In large buildings—shops, warehouses, hotels, and so on—the case for multiple switching is even stronger, owing to the larger number of lamps and the greater variety of purposes. To illustrate this point we may take the case of a warehouse in which goods are stored in a series of racks reaching from floor to ceiling. Every alley-way has to be provided with light, and unless the lamps in each alley-way can be controlled from several points an immense amount of light will be wasted in the course of the working day. To collect the material for a single order a man may

have to go to a dozen racks in different parts of the warehouse. Human nature being what it is, he will not retrace his steps to switch off the light in an alley-way he has just left ; and even if he did he would be wasting time which could be saved by providing switches at both ends of each alley-way.

In hotels, again, it is necessary to ring the changes on the corridor lights. Certain lamps must be kept on at all hours, night and day ; others are burning all night. It is not only convenient but essential to safety that the different groups should be under control of the management from suitable points. Similar arguments apply to the lamps in dining-rooms, reading-rooms, and other parts of the hotel. Unless the circuits are well subdivided and the switches arranged to make the turning out of unnecessary lamps an almost automatic affair, the bills for electric light may well be double what they need be. The desire to save initial cost has often led proprietors to simplify the switching arrangements, but in so doing they are increasing their running expenses and depriving themselves of one of the greatest of the secondary advantages of electric light.

The art of switching is peculiar to electric light, as the electric lamp is the only one which can be readily controlled from a distance. The art of illumination is, of course, common to all forms of light, but it has reached its highest point in the case of electric light. This is due to three things. First, electric lamps can be readily placed in any position—on ceilings, on walls, on floors, or at any point in the intervening space. Second, they are obtainable in a very wide range of candle-powers, from a night-light up to a searchlight. Third, their light can be reflected and diffused with the utmost facility to produce any desired kind of illuminating effect.

Illumination is a science. There is an Illuminating Engineering Society composed of experts who give a close study to the technical problems of the intensity, the diffusion, the reflection, and the distribution of light in relation to the eye which sees and to the things which are to be seen. Yet it was only recently that the scientific nature of the problem was

realised. And to-day there are thousands, nay millions, of people who judge whether illumination is good or bad by simply looking at the source of light. If the source is brilliant, they call it a good light. If not, not !

In the last resort, of course, the human eye is the true test of good lighting. When the illumination provided enables us to read or write comfortably, to move about in the streets with safety and confidence, to operate machinery with accuracy, or otherwise ensures that the light serves its particular purpose without imposing any strain on our eyes, it is good illumination. But mere brilliance in the source of light is not enough to bring about these results. It may even be a hindrance to them.

Three things are essential to good lighting. The source of light must be in the right position. The light it provides must be properly diffused. And thirdly, the illumination must be adequate for the work in hand, whether reading, writing, eating a meal, or working embroidery, or operating a tool.

Another way of saying the same things is to lay down the law that artificial light should resemble natural light at its best. Daylight, as it reaches us in our rooms, offices, or factories, is by no means always at its best. On dull mornings or afternoons it may be inadequate. On bright days it may be too glaring, so that we have to lower the blinds to cut off the direct rays. Daylight, in fact, varies with the time of day, the season, and the state of the weather in a way we would consider to be most inefficient if sunlight were supplied to us under contract by a limited liability company. The best samples we get of it are in the artist's studio, which is generally a room with a large window facing the north. Direct rays of sunlight never reach the room. It is illuminated by light reflected from the blue sky, from the clouds, and from trees and other objects. All this light from an invisible source is diffused throughout the room. There are no sharp contrasts between light and shade ; no abrupt black shadows ; no gloomy corners. A soft, pleasant, adequate light pervades.

A similar effect is gained in factories with roofs of the saw-tooth pattern. Here the slopes of the roof facing the south are opaque and the steeper slopes facing the north are



AN EXAMPLE OF SCIENTIFIC INDUSTRIAL LIGHTING

The lamps are arranged in metal reflectors, which prevent glare and distribute the light evenly over the working plane.

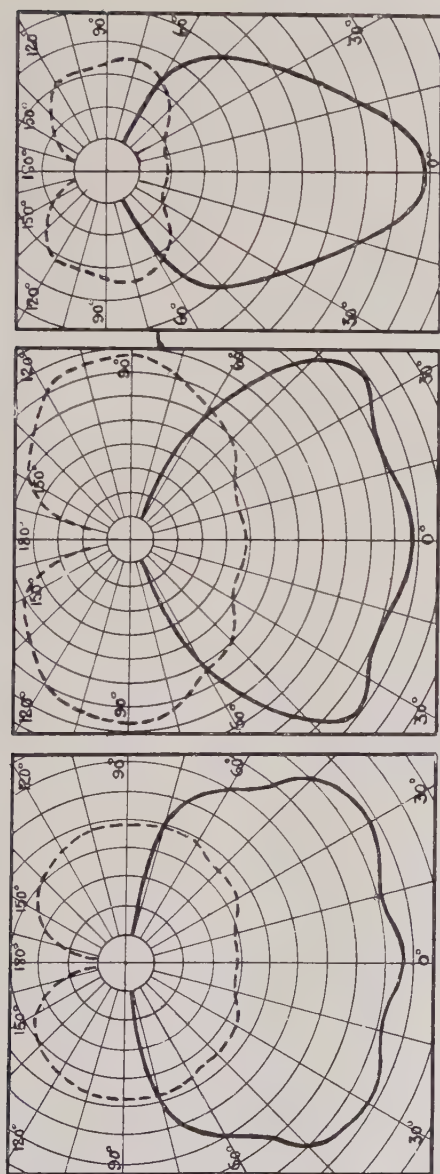
This photograph was taken by the light of the lamps.

glazed. Every part of the factory is thus provided with a good north light, and every machine is adequately furnished with an evenly diffused illumination. The operators never see the sun while they are at work, but they enjoy sunlight in its ideal form—the indirect. Even on days that are overcast the illumination is better than would generally be obtained from windows facing south, because the indirect light is more uniform than the direct.

The ideal form of natural light is clearly the goal at which artificial light should aim. But not until electric light came along was it possible to make any approach to the goal. And even electric light had gone through several stages of evolution before the effect of indirect sunlight could be imitated without extravagance both in lamps and in current.

When electric lamps were first invented they were used to imitate gas lamps and oil lamps, not the light from a northern sky. Gasaliers were often converted into electroliers by threading wires through the pipes and putting lamps in place of the jets. New electroliers were designed like gasaliers, except that the lamps were arranged to hang downwards at an angle instead of being upright. In both cases frosted or opalescent glass shades were used to modify the glare of the light. Electric table and floor standard lamps were exactly like oil lamps; in fact, many people had their oil lamps adapted for electricity, and to-day one can see in the shops many decorative types of electric table lamp with a bowl-shaped body which reminds us of the oil lamp. Candles in sconces and on the table were also imitated by using small electric lamp bulbs on the top of translucent white stems.

The most satisfactory of these imitations was the electric standard lamp. With its tinted silk or paper shade it was free from glare, and it diffused a soft pleasant light over a wide circle. It was then—and still is—very popular for reading, writing, sewing, and other purposes where “local” lighting is appropriate. But about the electrolier, which was the orthodox thing until recent years, it is not possible to speak with much enthusiasm. It was a makeshift. The lamps were hung low in order to get them near to the objects to be illuminated, but in that position they were close to the line of



Diagrams showing the three types of light distribution afforded respectively by "extensive," "intensive," and "focussing," or "concentrating," reflectors. The dotted line in each case shows how the light is distributed from the bare lamp. The black line shows how the reflector diffuses the light downwards and outwards to give efficient illumination.

sight and shone almost directly into the eyes of people moving about the room. "Light on the object and not in the eye" is the first law of good lighting, and if it needs any proof one can get it by walking in a westerly direction on an evening when the sun is setting in a clear sky. The strong light falling directly on the eyes is not only painful and irritating, but it prevents one seeing the landscape clearly. It is a relief to turn one's back to the sun; and in that position everything both near and distant stands out in full visibility.

Another familiar example of the effect of light shining into the eyes is afforded by the ordinary unshaded candle. When the candle is held in the usual way, somewhere in front of the eyes, little but the candle can be seen. Only by shading the light with the hand or by holding the candle high above the head can the objects around be made visible. In a certain famous volume of memoirs it is related that the heroine and her lover had met secretly in the dining-room of her home when her father descended with a candle to have a good-night look at his beloved pictures. He made the tour of the room and passed within a few feet of the anxious couple without seeing them. The authoress, not being of a scientific turn of mind, did not make any observation on the effect of a bright direct light in contracting the pupil of the eye and thus reducing the power of seeing adjacent objects. But it was to that she owed her immunity from discovery.

By fitting the lamps in an electrolier with shades the glare was somewhat diminished, with a considerable waste of light. The result was far from ideal, as we may gather from the frequent references in the novels of the period to the "hard glitter" of electric light. It is important to remember that the glowing filament of carbon was both a smaller and a more intensely brilliant source of light than the flame of oil or gas. Many people, in fact, preferred the oil lamp in particular because of its softer light. There was all the more reason, therefore, for giving attention to subduing the glare of the electric lamp so as to give a pleasant diffusion without losing too much light.

Quite the best solution—though it was rather an extravagant one—was that applied by Colonel Crompton when electric

light was installed in Buckingham Palace. A row of lamps was placed behind a cornice which hid them from people in the room. They illuminated the ceiling which, being of a light tint, reflected the light downwards and flooded the room with a soft, diffused illumination. This was one of the first examples of "concealed lighting" and it reproduced very faithfully the natural illumination from wide north windows or a saw-tooth roof.

We shall see presently how "concealed lighting" later came into general use on a more economical basis. While carbon lamps were the only ones available, ordinary folk had to be content with two or three in an electrolier instead of a dozen or two behind the cornice. The faults of the usual electrolier, however, became more glaring, in every sense, when metal filament lamps were introduced. As mentioned above, these lamps were more intensely brilliant than carbon filament lamps. The bulbs were longer, consequently they stuck out beyond the "little pink petticoats" of glass which had shrouded the carbon lamp bulbs. Their greater glare was thus in part quite unrelieved. When used in the ordinary fitting they had a further disadvantage. The filament, being arranged in vertical straight lines, threw most of its light sideways and extremely little directly downwards, thus leading to waste of light upon the upper parts of the walls.

Electrical engineers were quick to realise these drawbacks and to find means for removing them. They saw that the old shades, which did little more than absorb light, must give place to reflectors which would use all the available light and distribute it in the most efficient way. They saw that the lamp and its reflector must be treated as twin appliances working together to produce a certain illuminating effect. In a word, they began to treat illumination as a science.

Their first efforts were directed to improving *direct* lighting—that is to say, lighting in which the rays are thrown directly from the source upon the area to be illuminated. They introduced bell-shaped or spherical reflectors of prismatic glass which diffused most of the light from the lamp downwards and outwards. A single lamp fixed at the centre of the ceiling of a small room would thus, with the aid of such a reflector,

shed its strongest illumination over the floor, furniture, and lower part of the walls. These are, of course, the portions where light is most wanted. Sufficient light, however, passes through the reflector sideways and upwards to illuminate the ceiling and the upper part of the walls.

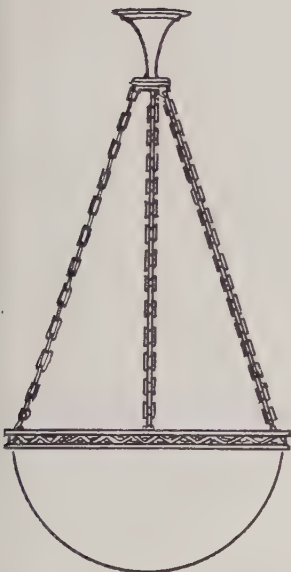
By altering the design of the reflector the distribution of light could be changed to suit any conditions. Three standard types of reflector were developed for general use—the “extensive,” the “intensive,” and the “concentrating.” The first gives a wide distribution suitable for a room with a low ceiling: the second diffuses the main part of the light over a narrower area and is therefore adapted to small rooms with high ceilings: and the third, as its title of “concentrating” indicates, gives a strong patch of light in a more restricted space under the lamp and is therefore useful in lofty passages or over landings. A fourth type—the “focussing”—less generally used, gives an even greater concentration.

It is not difficult to realise how flexible and how efficient these reflectors make electric lighting. Whatever the shape of a room or the purpose for which it is used, the appropriate illumination can be secured by ringing a few simple changes on lamps and reflectors. Small rooms, as already indicated, can be well lighted by a single lighting unit (lamp and reflector combined) in the centre of the ceiling. In larger rooms two or more lighting units can be hung at certain intervals to supplement each other and provide uniform illumination all over. Given the plans of a house, an illuminating engineer can specify the exact position and character of all the lighting units necessary to give the degrees and distribution of light appropriate to sitting-rooms, hall, bedrooms, and all other parts of the building.

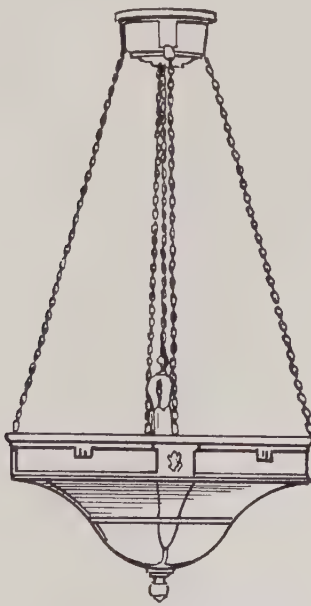
When these reflectors came into use, the old electroliers went out of fashion, and lamps ascended from near the line of sight to near the ceiling. This rise led to a great improvement in the hygienic aspect of electric lighting. Although a lamp covered with its bell or globe (which concealed the filament) was not nearly so bad for the eyes as a bare or half-shaded lamp, it still provided a brilliant source of light; and the best position for it, therefore, was well above the line of sight, like



(1)



(2)



(3)

There are three standard methods of illumination—direct, semi-direct, and indirect. (1) is a reflector for direct illumination, all the light being directly diffused downwards and outwards. (2) is a fitting for semi-indirect illumination, some of the light being diffused through the translucent bowl and some reflected from the ceiling. (3) is a fitting for indirect illumination, all the light being thrown upwards by a reflector inside the opaque bowl and diffused from the ceiling.

the sun at noon. The high economy of the metal filament lamp, combined with the efficient way in which the reflector distributed the light downwards, made it possible to raise the position of the lighting unit and still get much better illumination at a lower cost than was feasible on the old system. With lamps placed high up there is no glare in the eyes. The metal filament lamp, it will be remembered, gives more light for the same current as compared with the carbon filament lamp. Combined with scientifically designed reflectors it gives improved illumination.

The reason why this advance took place in connection with *electric* lighting was simply that the electric lamp is the only one which can be closely and completely surrounded by reflecting surfaces of any desired form. Further, it is controlled by switches and therefore need not be hung at the low level required in a lamp which has to be lit. An electric lamp can, in fact, be put anywhere to serve any kind of illuminating purpose.

Great as was the improvement in illumination brought about by these reflectors in combination with the metal filament lamp, it was by no means the summit of progress. Direct lighting, it may be noted, is still some way from the ideal of a "north light" provided indirectly from an invisible sun. Excellent though the diffusion was, the fact that most of the light came directly from a source only a few square inches in area gave the illumination a certain hardness. Here the æsthetic element enters into the question. The "soft" light which is so restful to the eyes and so pleasing in other ways must come from a large area not itself so bright as to suggest any glare.

In answer to the desire for this kind of illumination, the "indirect" lighting system was invented. The lamp is hung inside an opaque bowl suspended from the ceiling and containing a silvered glass reflector which throws all the light upon the ceiling. Thus the lamp itself is invisible and the room is illuminated indirectly by reflection from the ceiling, as in the Buckingham Palace example described above. At first sight this seems a very wasteful form of lighting, but in reality it is not so. The reflector in the bowl is highly efficient, and a

white-washed ceiling returns about 80 per cent of the light which falls upon it. So that the proportion of light which is usefully diffused over the room is actually very high. Moreover, the gasfilled lamp is admirably adapted for indirect lighting ; indeed, for domestic illumination it should hardly be used in any other way. And it gives so much light for so little current that there is no need to quibble over a little less efficiency when the main thing in view is perfection in *illumination*.

As with direct lighting, a room of average size—such as the dining-room or drawing-room of the modern villa or semi-detached house—can be illuminated indirectly by a single fixture in the centre of the ceiling. The flood of light from the invisible source suffuses the whole room with a restful radiance which is “ good for the eyes ” in every sense of the term. Large rooms can be dealt with by using a more powerful lighting unit or by using more than one unit. Should a more concentrated light be desired at any part of the room for sewing, embroidery, drawing, or other special purpose, it can be supplied by a shaded standard lamp.

Nothing could better illustrate the flexibility of electric lighting than the fact that a room can be beautifully and sufficiently illuminated from a single standard fitting. Two sets of lamps are provided in this fitting, the upper one being arranged in a reflector bowl and the lower in the ordinary way for downward illumination. If “ local ” lighting alone is desired, the lower set is switched on. If “ general ” lighting alone is wanted, the upper set is used. When both sets are in use the room as a whole is lighted by reflection from the ceiling, while concentrated light for special purposes is afforded in addition. The sources of light are in all cases invisible, and the illumination charmingly diffused.

A third system of illumination, which is a blend of the direct and the indirect, has become very popular. As in the indirect system the lamp is hung in a bowl suspended from the ceiling, but in the “ semi-indirect ” system, as it is called, the bowl is translucent, being made of opalescent glass or alabaster. Part of the light passes directly through the bowl and part is thrown on the ceiling and diffused therefrom by

reflection. The general effect is soft and free from unpleasant glare, but the presence of the bright bowl gives a touch of brilliance which many people find attractive and stimulating. Choice between the indirect and the semi-indirect systems is almost a matter of taste. Some authorities claim that the indirect system is perfect, and that when people get used to it they will be content with no substitute. Other critics, however, declare that pure indirect lighting is monotonous ; they seek the tonic affect of the feeling that the sun is in the sky even though they do not want to look at the sun. The practical point for the user of electric light is that he can obtain, with stock fittings, any kind of illumination he desires.

So it is not uncommon to find all three systems of lighting in one house. The hall, for example, may have a semi-indirect lighting unit ; the drawing-room may have indirect illumination ; and in the bedrooms, passages, kitchen, scullery, and so on, various forms of direct lighting unit may be installed. In selecting the positions for the various units, the size of the lamps, and the nature of the fittings, a certain amount of expert knowledge is required to ensure good results. Recognising this fact, more than one electric lamp-making firm has established an Illuminating Engineering Department to provide free advice to anyone installing electric light.

Although the electric lamp of to-day is about six times more economical than the electric lamp of twenty years ago, the amount of current consumed for electric lighting in the average house is not usually six times less. The reason is that people have used the more efficient lamps to provide more light rather than to reduce their electric lighting bills. In other words, the standard of illumination has been raised. Few of us would be content to dress and undress by the candlelight which our grandparents considered quite good enough even for genteel folk ; none of us would be content if our living rooms had no better illumination than what our parents considered to be a blaze of light.

This increase in the volume of light in the home has been all to the good. Light is a tonic ; gloom and darkness are depressing. Plenty of light all over a house helps the inmates



DRAWING-ROOM ILLUMINATED ON THE INDIRECT SYSTEM

In which all the light from the lamp is thrown on to the ceiling and reflected therefrom in a diffused glow all over the room. In the fire-place is an electric fire, specially designed to give a pleasant flickering effect.

to be cheerful, and makes both work and play more pleasant. There is no reason why, with gasfilled electric lamps, every man's house should not be as brilliantly illuminated at night as it is on a bright summer's day. Hitherto most of us have been obliged, for reasons of cost, to make the best of artificial light at a much lower standard than natural light at its best. With electric lamps six times more efficient than of old, and fitted with far more efficient reflecting devices than were formerly available, we can have six times more light without using any more electricity than people were content to use in the earlier days of electric lighting.

Much that has been said about the progress of electric lighting in the house applies also to illumination in factories, shops, and streets and other open spaces. Nevertheless, it is interesting to trace how electric light has adapted itself to the special requirements in these cases and how it has improved the conditions under which business and traffic are carried on.

Factory lighting is a special branch of illuminating engineering, because factory buildings differ so much in dimensions and character, and because each process—spinning, weaving, machine-tool operating, printing, or what not—requires a special standard of illumination. The broad general principles, however, can be stated briefly enough. Every factory requires a certain amount of uniform general illumination, free from glare and cross-shadows, so that the workers can operate the machinery with ease and safety. Frequently it is necessary to reinforce the general illumination with local lighting, as, for example, over cutting tools and linotype keyboards. Before the days of metal filament lamps these requirements were met by installing arc lamps at regular intervals high up and by suspending carbon lamps with conical metal shades over individual machines, or, in some cases, fixing them on the framework of machinery. To-day the gasfilled lamp has almost completely displaced the arc lamp for general lighting ; and local lighting is carried out by metal filament lamps of either the vacuum or the gasfilled type.

Here, as in the domestic field, the improvement in the lamps themselves was accompanied by a more efficient use of the light they provided. Arc lamps, as usually installed in

the old days, wasted much of their light upwards and gave an unequal distribution of light. Every gasfilled lamp for industrial purposes has its appropriate fitting—a translucent globe or bowl and an upper reflector—which diffuses the light so that a number of such lighting units, placed at a certain height and at certain distances apart, will furnish an even flood of illumination all over the “working plane.”

In local lighting the old conical shade of enamelled iron so commonly used with carbon lamps has given place to scientifically designed metal reflectors which diffuse the light downwards and outwards in much the same way as the prismatic glass reflectors described above. They also are made in four specific forms—extensive, intensive, concentrating, and focussing—each of which serves a definite purpose. The form of the reflector determines the distribution of light from it, and as the interior is lined with a highly reflecting covering, its efficiency is very high. One great feature of this industrial lighting unit is that the reflector extends to the level of the pip of the lamp, so that the lamp itself is invisible at the ordinary angle of sight. All glare is therefore absent from this system of lighting. A lamp fitted with such a reflector may be placed right in front of a worker and throw its full light on a tool, a scale, or any other part of the machine that requires careful inspection, and yet cause no eye-strain.

In addition to these two types of factory illumination there is a third—“localised general”—often used in workshops, especially where the workers sit at benches assembling parts, or finishing off articles, or sewing, or performing any other operation that requires a fairly high degree of general yet not too diffused lighting. Lamps are hung about ten or twelve feet above the floor and at such distances apart that the illumination along the benches is uniform. The metal reflectors shroud the lamps from the sight of anyone looking across the workshop, so that there is no distracting glare.

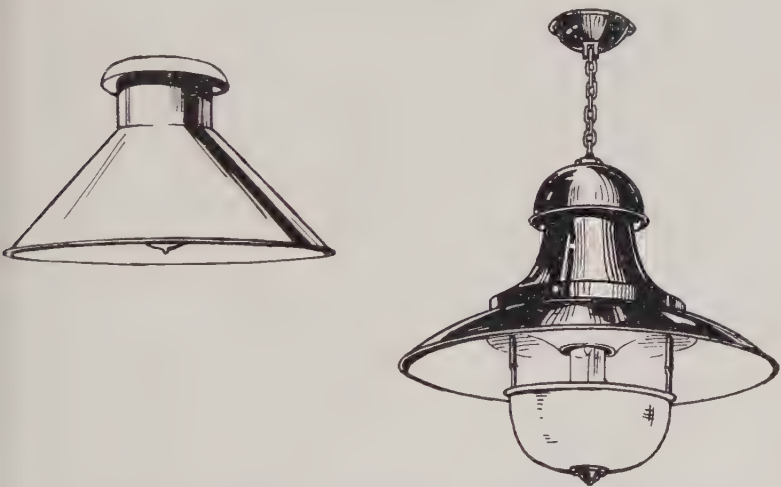
From these brief particulars it will be clear that, as in domestic lighting, every variety of requirement in industrial lighting can be met by the skilful use of incandescent electric lamps and stock reflectors. In factories also there has been a marked rise in the standard of illumination since gasfilled

and other metal filament lamps were introduced. The cheapness of electric light has encouraged factory owners to use more of it ; and the production of scientifically designed reflectors for all purposes has led to the more efficient use of it. From this improvement has come a long train of benefits both to employer and employed.

In 1913 the Home Office formed a Departmental Committee to inquire into the subject of industrial lighting ; and the first report of that Committee, issued in 1915, was to many people a revelation of the far-reaching importance of good lighting. Bad lighting, it was proved, led to accidents both to men and machinery. It also led to machinery being badly tended and maintained, because of the difficulty of cleaning or adjusting parts which are left in semi-darkness. Many breakdowns could be traced to this source. The health and the spirits of workers are affected by inadequate lighting, not only because lack of light is depressing but because any strain on the eyes reacts upon the nervous system, leading to headaches and irritability. Dark corners, again, are apt to become dirty corners ; and dirty corners are the haunts of disease. Most important of all, from the strictly business standpoint, is the fact that good lighting increases output. To say that " light is a tool " is to express in an epigram the value of adequate illumination to the worker. He gets through his work quicker and with less effort, and he is not so liable to spoil it, if he operates well-lighted machinery. The movement of parts from point to point in the process of manufacture, and the general supervision of the factory, are also facilitated by perfect illumination.

Bearing in mind that the cost of lighting a factory is only a tiny fraction of the total expenses of production, being sometimes less than 1 per cent of the wages bill, it is clear that more and better light is sure to be an excellent investment. Putting the matter on a higher plane it is the duty of every factory owner to provide his workpeople with illumination which will ensure their safety and their good health. With the latest types of electric lamp there is no economic obstacle to the performance of this duty, even setting aside the monetary benefits of greater output and improved quality.

In the lighting of shops many things have to be taken into account besides the simple necessity of providing enough light for assistants and customers to do their business conveniently. The ideal light for shops must have a brilliant quality, which makes goods look their best. It must be a cool light and free from fumes, because hot vapours have a bad effect on stock of various kinds, especially when it is stored on high shelves. The lamps must be such that they can be hung in any position, close if need be to stock of an inflammable character. All the



Two types of fitting specially designed for industrial lighting. In the right-hand type the lamp (gasfilled) is concealed from view by a translucent globe. Both types are designed to give good diffusion without glare.

lighting units should be under immediate and convenient control, since the lighting demands in various parts of the shop vary with the daylight conditions. There should also be complete facility in distributing the illumination so as to secure the finest decorative effects on displays of stock in windows and show-cases and on counters.

All these conditions are fulfilled by electric light, and by electric light alone. It is not surprising, therefore, that electric light has been popular in shops ever since the days when arc lamps and carbon filament lamps were the only lighting units

available. To-day, with metal filament lamps of the vacuum and gasfilled types, electric lighting has become practically universal in the better-class shops. All three systems of lighting—direct, semi-indirect, and indirect—are applicable to shops, but the requirements are so varied that it is impossible to speak in more than the most general terms about how each should be used. For counter lighting the direct system is usually employed, the lamps being hung at regular intervals on a level about ten feet from the floor and fitted with reflectors which protect the eyes from glare and diffuse the light uniformly over the counter. In such places as the show-rooms and trying-on rooms in dressmaking establishments, the indirect system is favoured because of its soft diffused illumination, which enhances the appearance of fabrics. For the general lighting of stores semi-indirect units are most popular, owing to their combination of brilliance and uniform illumination. It frequently happens that no convenient ceiling is available to act as a reflector; in such cases the fitting is surmounted with an "artificial ceiling" in the form of a large disc coated white to give it a high reflecting power. In getting the best effect from each system, according to the architecture of the building, the lay-out of the stock, and the character of the business, the advice of an expert is really essential.

Connected with shop lighting there are two special problems of great interest—one the effective illumination of window displays and the other the matching of colours by artificial light.

In spite of all the progress in electric lighting and in spite of the many good examples which ought to impress competitors, a vast number of shop windows are very badly lit. Their besetting sin is not that they have insufficient light but that they have too much of it, and in the wrong place. The object of lighting a window is to display the goods to the best advantage. They should be clearly visible to the passer-by, and the illumination should be free from glare or dazzle which will irritate or strain the sight. These observations are only common sense, but in countless cases they are absolutely ignored. Bare lamps—even the super-brilliant gasfilled lamps—are hung just inside the window at and below the eye level, so that they shine into the eyes with the blinding effect of a low sun.

Instinctively the eyes *turn away* from the excessive glare. The light, in fact, acts as a screen in front of the goods which the prospective customer is desired to examine at his leisure and with a sense of pleasure.

Perhaps the best treatment for those who thus abuse the blessings of electric light would be to oblige them to attend a theatrical performance where the footlights were not screened from the audience. They might then realise that a shop window is in effect a stage, and should be lighted as a stage is lighted—with an ample flow of light from concealed lamps. Theatrical managers have discovered that a row of unshaded lights along the front of the stage effectively prevents the audience seeing what goes on during a change of scene. Such a curtain of light was also used by licensed houses in an American city which passed a by-law to the effect that no obstructions were to be placed in the windows of saloons—the object being to enable the police to observe what went on at the bar. A row of blazing arc lamps inside the window did not form an obstruction within the meaning of the law, but it gave the revellers as much privacy as a brick wall.

With electric light it is a simple matter to get the stage effect in lighting a shop window. Lamps can be placed on the inside of the window frame at any point and concealed by metal reflectors which, according to their shape, distribute the light in the manner desired over the goods in the window. For various reasons it is usually most convenient to confine the lamps to the top of the window and to use reflectors which throw all the light downwards and backwards so that none is wasted on the pavement. With this arrangement the window can be “dressed” fairly close up to the front and yet all the articles are flooded with light so well diffused that every detail, even to the odd halfpenny on the price ticket, can be examined with comfort. The whole window stands out like a bright picture in a dark frame, with a most cheerful and inviting effect.

Colour matching by artificial light is a fascinating problem to which many scientific men have turned their attention. The light from a gasfilled lamp is, owing to the intense brilliance of the filament, closer to daylight than the light of any

other electric lamp save certain forms of arc lamp. It is not, however, close enough to make colour matching safe, and its light requires to be modified to the daylight quality by passing it through a globe of special glass or by reflecting it from a tinted surface. The latter plan is used in the "Sheringham light," invented by the artist, Mr. George Sheringham. He uses indirect lighting in which the upper reflector is formed by a kind of flat umbrella painted in small squares of green, blue, and other colours which "correct" the quality of the light thrown up by the lamp.

The great difficulty in this problem, however, is that there is no such thing as standard daylight. The colour of daylight varies with the atmospheric conditions. Colour matchers do not work on dull or foggy days; they prefer a north light from a clear sky. In future, perhaps, the textile trade will fix on a standard daylight which can be accurately reproduced by electric light, so that matching may be carried on without interruptions by fog or smoke or cloud.

Street lighting is a very important matter from more than one point of view. The safety of traffic, both vehicular and pedestrian, depends largely upon the good lighting of thoroughfares. Public security also requires ample light; as Mr. George R. Sims once neatly expressed it, "one arc lamp is worth two policemen." And again, brightly lit streets have a tonic influence on the spirits of the public. Who is not depressed by dark ill-lit roads, or enlivened by the blaze of a main business thoroughfare? Who does not remember the gloom imposed upon London and many other cities by the restrictions upon lighting during the War?

The dislike which people felt for the meagre illumination of our streets during the days of air-raids was highly significant. We were revolted at the darkness made visible by occasional feeble glimmers, yet the standard of illumination was not much lower than that which our grandparents contentedly accepted as a matter of course. In pre-electric days very little was expected from street illumination. Some not too distant gleam to guide the footsteps was enough, save in a few selected thoroughfares in the great cities. Traffic, however, was leisurely and went ahead safely enough under the lights it



A striking example of the wonderful effects which can be obtained by various modes of electric lighting. The ground floor is illuminated by concealed lamps, giving a stage effect.

carried. The demand for something better grew insistent with the development of faster traffic and the general increase in the nocturnal activity of city streets. When the arc lamp became available it set a new standard of brilliance in street illumination and fired the ambition of city fathers to outshine each other. Incandescent electric lamps were also introduced for the lighting of side streets with great advantage. But not until the appearance of the metal filament lamp, and especially of the gasfilled type, did the city engineer obtain a measure of illumination which he could use lavishly (by comparison) in highways and byways. Just as in the case of homes and shops and factories, the general standard of illumination in streets has been raised enormously by the invention of the gasfilled lamp.

In street lighting, again, there has been a great advance in the method of using electric light. It used to be the custom to hang bare lamps at intervals on alternate sides of the streets—an arrangement which gave bright patches with intervening dark spaces. A certain amount of distracting glare also resulted. Modern street lighting corrects both faults by fitting each lamp with its appropriate reflector which distributes the light efficiently and evenly over a wide area. It is a well ascertained fact that uniform illumination, obtained in this way, gives better visibility than patchy lighting even though the total amount of light is not nearly so great. In arranging its street lighting, therefore, an up-to-date public authority does not speak of the candle-power of the lamps to be installed ; it specifies the amount of light which must be diffused over the roadway. Limits are placed beyond which the illumination must not go, in either direction, so that a close approach to uniformity is obtained. However rigorous the requirements, they can be readily and economically met by a well-designed electric lighting system.

Electric light is to-day, however, so much more efficient than it used to be that public lighting authorities may well feel encouraged to go above the standard necessary for safety. The London " Safety First " Council has suggested three degrees of illumination, the first for densely crowded streets in the centre of the city, the second for ordinary main thoroughfares,

and the third for side streets. It has also drawn attention to the necessity for shading off the degrees of illumination at junctions of roads of different classes, so as to avoid the dangers of a sudden change in the intensity of light. But after safety has been secured, amenity may be considered. The human organism loves light and is drawn towards it as irresistibly as the moth seeks the candle. Why should a city, as a city, not set out to make itself more attractive by the generous illumination of its thoroughfares? Many towns spend large sums of money in improving and in advertising their daylight amenities, but after nightfall these are hidden behind what is, in effect, little better than semi-darkness.

The only people in our towns who really appreciate the drawing power of light are the proprietors of places of entertainment—theatres, music-halls, picture palaces, and public-houses. Light—a lavish display of electric light—is their most powerful magnet. Some business establishments, it is true, have followed suit and made their premises a beacon, but rarely are the full possibilities of electric light as a brightener and quickener of the life of a city realised. In this matter we may take a lesson from some American cities, which have converted once sober thoroughfares into glowing “white ways.” Shopkeepers and the civic authorities have co-operated in flooding the street with light so that it resembles an avenue in some great exhibition rather than a business thoroughfare. The main object in view is, of course, to attract customers to the shops; and from that standpoint “white ways” appear to be so successful that our commercial leaders might well follow the example. But they have a broader lesson, especially for these islands where the winter climate is in itself depressing. Our cities would be happier if they were truly cities of light.

In dealing with the business value of light it is impossible to avoid a reference to electric signs. Here there is a conflict of feeling between the “common man” and the artistic and civic authorities who defend our towns against the intrusion of anything ugly or vulgar. The authorities pass stringent by-laws prohibiting sky-signs and regulating the size and position of signs fixed to buildings. The artists write violent letters to the papers whenever the sombre tones of some

Whistlerian vista suffer the intrusion of an electric sign which winks out its invitation to drink somebody's whisky or somebody else's tea. Nevertheless, the public eye unquestionably takes pleasure in the light and colour and liveliness of the signs which beam across the gloom of misty rivers or glitter along the dark walls of city streets. Admitting that many electric signs are crude and blatant, the fact remains that the average eye delights in them. Their faults can be corrected by better design ; and perhaps, when the all-electric city comes near to realisation, our artists will not disdain the task of using the instruments of light and colour to achieve æsthetic harmonies and contrasts. The appeal which the electric sign makes is akin to that of fireworks ; and our fireworks are generally acknowledged to be beautiful enough, although their beauty is not of the kind to which the art critic pays much attention.

There is still another application of electric light which has both artistic and commercial values. The usual way of illuminating the face of a building is by hanging brilliant lamps in front of it, with the result that while the lamps are intensely visible the architectural features of the building are obscured by the glare. A much better way is to flood the whole of the structure with light from concealed sources. The building then shines out as if it were itself luminous, and every detail is clearly visible. This effect is obtained by using a number of gasfilled lamps in reflectors shaped somewhat like the headlights of motor-cars. The reflectors (or, rather, projectors) throw a widening beam of light, and a battery suitably arranged will uniformly illuminate a tower or a facia. In the States, where the clearness of the atmosphere is a great advantage, " flood lighting " has been used to illuminate sky scrapers, monuments (like the statue of Liberty), and exhibition buildings. Even the Niagara Falls have been treated in a similar way.

With our hazy atmosphere, and the grimness of our buildings, it will be impossible to get the same white radiance by flood-lighting our city buildings. But certain attempts which have already been made, notably in illuminating the tower of the municipal buildings at Glasgow during the Peace celebrations, indicate that the decorative possibilities of flood-lighting



THE MODERN METHOD OF SHOP-WINDOW LIGHTING

Is by means of concealed electric lamps fitted with special reflectors which diffuse the light over the goods to be displayed. The effect is a bright picture in a dark frame. This photograph was taken by the light from the windows themselves.

in this country are worth exploiting. The commercial possibilities are, however, more important. Flood-lighting has been largely used in the States for the protection of goods stacked in the open and also for enabling constructional and other work to be carried on at night. It has been found that a ring of flood-light projectors round a coal depot or a timber yard is a much more effective deterrent to thieves than the most costly fencing. Anyone moving across the streams of light can be instantly detected from a long distance, and it requires a quite abnormal amount of criminal courage to engage in a marauding expedition on stores which are guarded by light. During the railway strike of 1919 the approaches to the power station of the London electric railways were protected by an emergency battery of flood-light projectors, and the threat of damage to the station was never carried out. Flood-lighting should therefore prove of great value in checking the pilferage which has lately been so rife in goods yards and docks.

For night work flood-lighting by electricity has the advantage over the flares usually employed that the source of light can be placed in any position and the illumination concentrated upon the business in hand. The nearest approach to the flood-light projector in common use is the "cargo bunch," the cluster of electric lamps hung over the hold of a ship in loading and unloading. But this is a primitive appliance compared with the flood-light projector, which is a younger brother of the searchlight that makes the navigation of canals and narrow waterways safe for the largest ships.

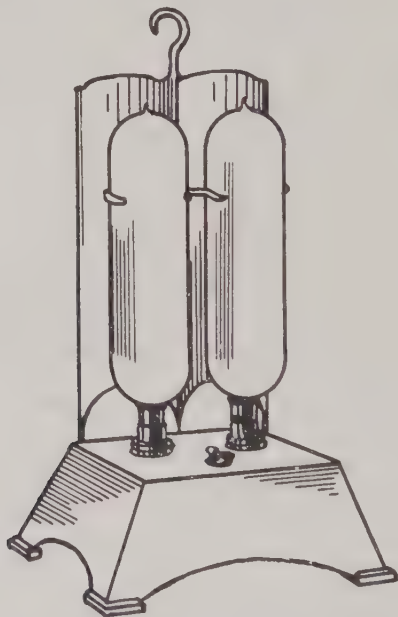
CHAPTER IX

ELECTRIC HEATING

HABITS of speech live long after the phrases have lost their original meaning. People still refer to electric heating and cooking, and even to electric power, as "auxiliary uses of electricity," thus implying that electric light represents *the* use of electricity. These auxiliary uses, however, take far more electric current than is consumed for lighting purposes. In point of actual demand for electricity, electric light is a trifle compared with electric power for traction and industrial purposes and with electric heating and cooking. It is only from the historical standpoint that these huge demands are auxiliary to electric light, which happened to be the first application that electric supply undertakings set themselves to exploit.

The first electric heaters, moreover, sprang from electric light. Electric incandescent lamps give off a certain amount of heat, though much less than a gas or oil flame of the same candle-power. (Electric arc lamps are, we may note here, a source of intense heat, and this fact is utilised in the electric furnace—an industrial application of electric heat which will be considered later.) Early in the history of electric light an effort was made to produce a carbon filament lamp which would give more heat and less light—would operate, in fact, as a source of radiant heat. The most suitable form was found to be a sausage-shaped bulb, lightly frosted, with a long hairpin filament. By arranging two or more of these heating lamps upright on a metal frame and backing them with a highly polished reflector, a very convenient "electric radiator" was made. Examples of this form still survive and are popular for the rich yellow glow they produce. The modern electric fire is, however, a much more efficient appliance.

The peculiarity of the lamp radiator is that it supplies nothing but radiant heat : that is to say, it warms the objects on which its rays fall, but does not heat the air directly. This is due to the heating element being in a vacuum, which transmits only radiant heat. In order to get an electric heating element which would warm the air by convection instead of by radiation only, inventors had to be content at first with very low temperatures. No alloy which was then known could be



THE EARLIEST TYPE OF ELECTRIC RADIATOR,
WITH LARGE GLOW LAMPS

brought to more than the dullest red heat without oxidising rapidly and crumbling away. The early electric convectors, therefore, were simply upright metal boxes, open at top and bottom, and containing a long length of wire warmed by the passage of electric current. The heated air rose into the room, which was thus warmed by convection.

To-day these "convectors" are obsolete, but they have more than an historical interest. Although they were more efficient than the lamp radiators in actually warming the air

of a room, they had no appearance of warmth and they did not make people *feel warm*. This drawback was got over by fitting a rose-coloured glass window in front of the convector and fixing an ordinary electric lamp inside, so as to give a red glow when the convector was at work. Strictly speaking, the red light was humbug, but in a human sense it was necessary. It is a fact that an imitation coal fire, artfully contrived with electric lamps, will bring comfort with its illusion of warmth. The moral for the inventor of electric heaters was that the heating element must combine both the reality and the visible sign of heat.

Eventually the difficulty was solved by the discovery of an alloy which could be kept at a bright heat in air without great deterioration for a very long period. That alloy contains nickel and chromium, and it forms the basis of modern electric heating and cooking in all their forms. It has a high electrical resistance, so that a small length of it forms a comparatively powerful heating element ; it can be drawn into flexible wires and ribbons so that it can be wound on or around insulators to form appropriate heating elements for fires, kettles, flat-irons, boiling plates, ovens, and other domestic and industrial appliances.

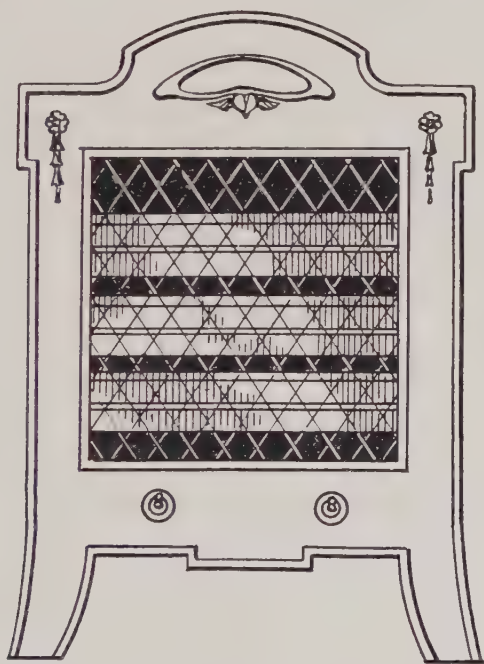
Imperfect as the first electric fires certainly were, they revealed the essential advantages of heating by electricity. For the first time it became possible to secure a source of heat under immediate control, if necessary, from a distance. The heater, again, was portable, and it involved no flame, no fume, no smell, no dust. The electric fire, in fact, paralleled the features of electric light, and it made its way, like electric light, more by its secondary advantages than on the score of the primary item of supplying so much heat for so much money. When the first electric lamp radiators were put on the market they were looked upon as hopelessly extravagant, because it was much cheaper to keep a coal fire burning than to run an electric radiator continuously. This objection is still valid, although modern electric fires are much more efficient than the old ones and electricity is much cheaper. Yet electric fires are selling by their thousands every year and the use of them has become firmly established.

In order to appreciate the secondary advantages of electric fires it is necessary to note the secondary disadvantages of coal fires. Setting aside the cost of the chimney, fireplace, grate, and accessories, and the space they take (more will be said about this important point later), we have a long list of daily drawbacks to the coal fire. First of all it has to be laid—a process demanding paper, sticks, coal, and a certain amount of ingenuity. Once lit, it takes half an hour or more before it begins to throw out any appreciable heat. Attention is needed at brief intervals to keep it burning brightly, but even with careful stoking it is difficult to control the heat. The fire, again, must be kept in all day, although the room may be occupied only at intervals during the day. Every fire is a continual source of dust, which spoils decorations and multiplies labour; and it involves a great deal of work in black-leading the grate, carrying coal and removing ashes, and cleaning the fire-irons. Add to all these the nuisance of smoky chimneys, the periodical visits of the sweep, and other incidental troubles, and one completes a catalogue which makes the coal fire, for all its bright benefits, a formidable cause of work and bad temper.

The case against the coal fire is summed up in the illuminating fact that the orthodox housewife will have no fires lit, save in the kitchen, after spring cleaning. Moreover, in the average home the use of coal fires is strictly limited to the one or two rooms which are in more constant use as living rooms throughout the day. In Scotland—the home of economy in labour as well as in money—a fire in a bedroom is an accepted sign that somebody is very ill. No matter how cold the season, ordinary folk are not supposed to have fires in a bedroom, dressing-room, bathroom, or any other room which they occupy only from time to time during the day. No matter how chilly the days of summer or autumn, the household law is that it is better to shiver than to endure the nuisance and dirt of a coal fire.

Putting the matter at its lowest, therefore, we may safely say that the coal fire does not adapt itself to all the needs of the ordinary household. And the main reason is that our habits, combined with our climate, call for an *occasional* mode of

heating. In countries with a continuously severe winter it is almost necessary to adopt central heating with pipes in every room, and to keep the heat going night and day. But in Great Britain a moderate warmth at instant command meets nearly all the needs of health and comfort. Consider, for example, how many uses can be made of the electric fire which would be out of the question with a coal fire. It can be



Example of modern electric fire with glowing elements, which give a high degree of radiant heat. Two switches are provided for controlling the heat.

switched on in the bedroom when one gets up in the morning, to take the chill off the air while we are dressing. It is invaluable in the bathroom after the morning tub. Switched on in the breakfast room for a few minutes before the meal is ready, it makes the room comfortable ; and when the meal is over it is switched off. Similarly with lunch, tea, and dinner. When one goes into the drawing-room to write a letter or play the piano, or when an unexpected caller arrives, the electric fire

meets the occasion perfectly. When the children's bath hour comes, they can be dried and dressed in front of an electric fire without any risk of catching cold.

So far as convenience and saving of labour are concerned, there can be no doubt about the superiority of the electric fire. A world of difference lies between obtaining heat at the touch of a switch and setting to work to get it by lighting a coal fire. Practically no labour at all is involved in the use of electric fires ; an occasional dusting is the limit of the attention they require. And here it may be emphasised that saving labour in the home is not a matter merely of convenience or comfort. It is a matter of hard cash. Domestic service was never more expensive than it is to-day, and anything which enables a house to be run with less of it is a source of real economy. Later on we shall see how other applications of electricity in the home save labour and thus help the all-electric home to pay for itself.

Used in the way described, however, the electric fire is very economical, apart from the money value of the labour it saves. The fire is used only where and when it is required, so that no heat is wasted. We may compare this feature with the ease of switching electric light on and off—a facility which is one of the great reasons for the economy of electric light. All the heat of the electric fire is thrown into the room, none of it being lost in chimneys ; from this standpoint the efficiency of the electric fire is unsurpassed. The ease with which the heat given out may be regulated is another advantage, the value of which is not so apparent. Modern electric fires are constructed with several heating elements controlled by switches so that full heat, half heat, or quarter heat can be readily obtained.

Before much experience had been gained in their use, the tendency was to design the fire on the small side, so as to save current. But in course of time it was found that a large fire with good heat regulation used less current. The applications described above require rapid heating at the outset ; enough heat is needed to take the chill off the room quickly. By installing a large fire and switching on full heat for a few minutes the temperature of the room is rapidly raised ; then the fire

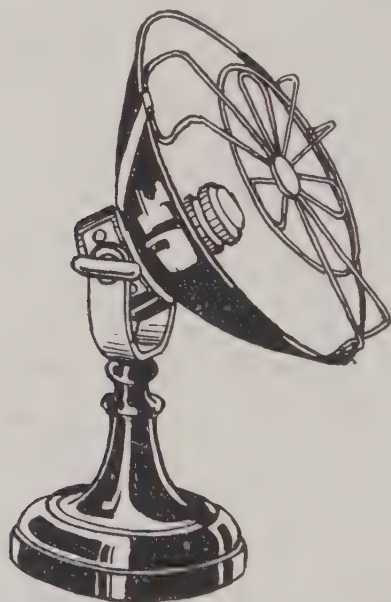
can be switched down to half or quarter heat, which is enough to keep the room comfortably warm. This method not only improves the usefulness of the electric fire, but reduces the total amount of current it consumes.

Electric fires with elements made of the special alloy referred to above have practically displaced both the lamp radiators and the convectors. They are, in themselves, both radiators and convectors—that is to say, they warm the air by direct contact and they throw out rays which warm everything they fall upon. Some forms give more radiant heat than others, and the choice depends largely upon the use to which they are put. We may note, however, that radiant heat gives a feeling of warmth, even though the air in the room be cold. The effect, in such circumstances, of switching on an electric fire is similar to the sun breaking through the clouds on a chilly day. Within a few seconds of switching on, the heat rays from an electric fire are strong enough to provide comfortable warmth to anyone sitting within range of them.

Advantage is taken of this fact in designing small electric fires suitable for use in bathrooms, bedrooms, offices, or other places where all that is needed is something to warm one person. The electric heater is arranged inside a conical polished reflector which throws a broad beam of heat; and anyone standing or sitting in the path of the beam is warmed as he would be in the sunlight. The reflector is made adjustable, enabling the beam to be thrown in any direction. With this concentrated mode of heating a very small fire (that is, one taking a comparatively small amount of current) gives a surprisingly good result.

Small electric fires also illustrate in the highest degree another advantage of electric heating—the portability of the appliance. It is often a great convenience to have a heater which may be carried from room to room and placed in any part of a room—close to a bed, under a table, alongside a desk. Many of the larger fires are also made portable, and one fire can therefore be made to do duty for several rooms in succession. This is an obvious advantage to people who are making the first steps towards the all-electric home. With one electric fire they can test the advantages and prove the economies of

electric heating ; and later on, as their means permit, they can give each room its appropriate fire, choosing—if they are æsthetically inclined—a design which will harmonise closely with the style of the existing decorations. Moreover, electric fires can be installed without disturbing the existing coal grates, which can thus be used at any time when extreme cold or a special continuous use of the room calls for a coal fire.

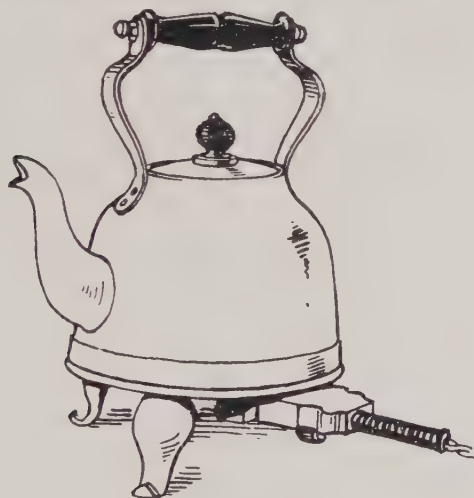


Small portable electric fire, which throws a beam of radiant heat. Fires of this type can be run from the ordinary electric lighting circuit.

Only the smallest electric fires can be used on the ordinary electric lighting circuits, as the larger fires take more current than the wires for electric light are intended to carry. The introduction of electric heating therefore involves special wiring, which is usually brought to wall-plugs, to which the fires are attached by means of flexible wires. Current taken thus for heating purposes is charged for at a much lower rate than the rate for electric lighting. Users of electricity sometimes find it difficult to understand why this should be so,

although they are grateful for the concession. The reason is, however, simply that the demand for electric heating is spread over the day and therefore helps to fill up the valleys in the "load curve" of the electricity station. Moreover, the price of current for electric light usually covers the "standing charges" involved in the service, and additional current can be supplied profitably at a lower rate.

The second main domestic application of electric heat is in the warming of water. This field may be divided into two parts—the boiling of small quantities of water, as for making



Electric kettle, with the heating element fixed in the base of the kettle. It can be used from the ordinary lighting circuits.

tea, or shaving, and the heating of large quantities of water for baths and for washing clothes and dishes. In the first case the crowning benefit of electric heating is its convenience. An electric kettle or shaving water heater or food warmer or coffee percolator can be connected up to any lampholder or wall-plug, and it therefore affords the readiest possible means of getting hot water in any room at any time. These appliances are made with an electric heating element in the case, the vessel and heater being thus combined, but it is also possible to heat water in any vessel by means of a separate "immersion heater"

which, as its name implies, is placed in the water itself. By either method practically all the heat is conveyed direct to the water, giving a very high degree of efficiency. As the amount of heat involved in boiling a pint or two of water is not large, electric kettles and kindred appliances can be used freely without unduly swelling the electricity bills, especially if current is taken from the special circuits mentioned above. And the ease with which the appliances can be used on the breakfast table, the afternoon tea-table, or at the bedside is a boon which is keenly appreciated.

Water may also be heated electrically by putting an ordinary kettle or other utensil on an electric boiling plate. This may consist of a circular metal plate with the heating element fastened to its lower side; it heats mainly by contact, like the hob of a coal range. Or it may have open elements, which heat the kettle after the manner of a clear fire. Neither form is quite so efficient as the self-contained appliance, but it is very convenient for many purposes. By very simple means several degrees of heat can be obtained, and at the lowest heat the plate takes the place of the spirit lamp for keeping dishes warm. As it involves no flame it can be used on the table with much more safety than the spirit heater.

In heating large quantities of water the same methods can be applied, but both the electrical and economic elements in the problem are somewhat different. If it is necessary to heat up several gallons of water quickly, the current consumption of the heater must be exceptionally large, and it may put a sudden embarrassing load on the mains. Moreover, if the housewife realises her desire for "hot water to waste" the total current consumption becomes considerable. Where electricity is cheap, this point does not matter very much. Therefore the practical problem is to secure electricity on the cheapest possible terms for water-heating purposes.

Bearing in mind that electricity can be supplied at a low rate when it helps to fill up the valleys in the load curve—that is to say, when other demands on the electricity station are not heavy—the way out of the difficulty becomes clear. Instead of heating the water by sudden heavy rushes of current, we can do it by a moderate amount of current applied steadily;

and we can arrange that the apparatus is not used during lighting hours or other periods of high demand. In effect, we store electricity in the form of heat, and we allow the storing process to take place only when current is available at the lowest rate.

When this system was first applied, the electricity was used to heat a block of iron through which cold water passed and was warmed when the tap was turned on. The only drawback to this arrangement was that deposits of lime formed in the narrow passages of the apparatus and gradually choked them. A much simpler system is now applied with complete success. The hot water tank is fitted with an immersion electric heater taking about one-third of a unit per hour, and it is covered with slag wool or other material to prevent the escape of heat. All the heat produced goes direct to the water in the tank and is retained in it. Alternatively, special electric water heaters can be installed in the bathroom or at any other spot where hot water is required.

A heater of this type, if left on all night, provides enough hot water for several baths and a good deal of washing up. The convenience of the arrangement is unsurpassed, as absolutely no labour or trouble is involved. To save labour is, as we have already emphasised, to save money ; and this factor should be considered in counting the cost. But apart from that factor, the efficiency of the arrangement is so high that, given a low rate for the current used, the actual cost is not high in relation to the expense of obtaining a similar service in the usual way.

The development of water heating on the large scale depends, it is apparent, on some means for switching off the heaters "during the peak." There are various ways of doing this. One is by a friendly arrangement with the consumer, who undertakes not to use the heater except in off-peak hours ; but very few engineers have enough faith in human nature to rely upon this co-operation. Another way is to use a "time-switch," which operates like an alarm clock, turning the heater off in the late afternoon and turning it on at night when the load on the station falls again. Recently the suggestion was made that the control should be done from the electricity

station itself, so that the engineer in charge could cut out the heaters whenever the load on the station became troublesome. If every heater were controlled by a switch attached to a simple form of wireless receiver, an electric wave sent out from the stations would instantly turn off the heaters. The same effect can, however, be obtained without wireless telegraphy. It is possible to send along the electric mains waves or ripples of high tension current which do not interfere in the least with lighting or other uses, but which operate special switches. This kind of "distant control" has been used to turn street lamps off and on, and could be applied equally well to electric heaters.

Many technical and commercial questions are, it will be observed, raised by the use of electricity for domestic water heating. No uniform answer can be given to all these questions, because the conditions of the problem vary so much according to local conditions—the cost of electricity, the amount of water required, and so on. But there is one point about the electric way which deserves to be emphasised. When an electric tank heater is installed for more or less continuous use during off-peak hours the user can easily discover exactly how much it costs him to obtain a hot water service. With the usual coal fire he has only the vaguest notion of the all-in cost of providing hot water; and if he did work out the thing in detail he would be confirmed in his impression that the process is very wasteful. The case is parallel to that of driving machinery, where the use of electricity brought a high degree of precision in place of a rule-of-thumb method under which extravagance could go on steadily without being detected.

As an alternative to the all-electric solution, many engineers recommend the use of both electricity and fuel. They urge that the cheapest way of supplying "hot water to waste" is by means of a slow-burning coke or anthracite stove which is never allowed to go out. Such a stove causes no smoke; it is easy to look after, as it requires stoking only twice a day and ash removal once a day; it is efficient, as it burns little fuel and transmits more of its heat to the boiler than is possible on a coal range; and it has the further advantage that it can be used to cremate rubbish. The plan suggested is to install such

a stove to keep the water in the hot water system at a moderate heat, and to use electricity whenever necessary to lift the temperature up to boiling-point for washing and other purposes. That is to say, electricity is employed simply for "topping up." If the stove alone were used for supplying boiling water, it would require to be forced at frequent intervals—a necessity which involves a great waste of fuel. On the other hand, very little electricity is needed to raise warm water to boiling-point, and the ease with which electric heaters can be switched on and off makes them an ideal auxiliary to the constant source of moderate heat.

The same plan can be extended to the heating of rooms and also to cooking. If hot water pipes are laid throughout the house the stove will maintain a constant circulation of warm water which, with a moderate consumption of coal, will keep the chill off the air in every room. In summer time, of course, the valve connecting the hot water pipes with the boiler is shut, and the flow of hot water is confined to the tank system. In winter any additional heat required at any time in any room is supplied by switching on electric fires, which thus top up the temperature of the room as the electric heater in the tank tops up that of the water. Not only does this arrangement make the use of electric heat very convenient and economical, but it makes central heating very cheap and well adapted to British conditions. In our climate the periods of intense cold are generally so short that it is an extravagance to install a central heating system large enough to heat the whole house when the thermometer is below freezing-point. Moreover, if we depend upon central heating to maintain every room at something between 60 and 70 degrees, we must have a large boiler and burn a great deal of fuel. Therefore it is cheaper to put in a small boiler which keeps the temperature at near 50 degrees and to use electric heat where and when needed for additional warmth.

The larger the house, the greater the degree of economy arising from this combination. In hotels, blocks of offices, and other large buildings, the alliance between constant low-grade warmth from a central stove and occasional local heating from electric fires gives a high degree of efficiency and con-

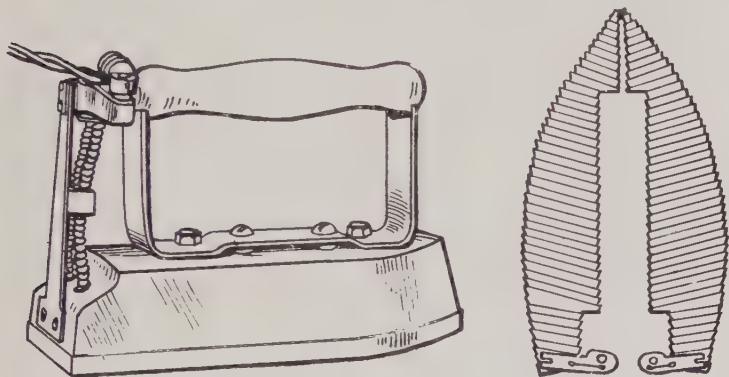
venience. Some people, it is true, regard the arrangement as a makeshift, good enough in its way until electricity becomes so cheap that there will be no need to trouble about keeping a fire going day and night. But there are many arguments for using the inflexible method of heating by a slow-combustion stove for providing a constant supply of warmth over a large area, and using the most flexible method of heating—by electricity—for local and occasional purposes.

The application of the system to electric cooking is on similar lines. When an oven is used for roasting or baking it must be brought to a high temperature : and if we use electricity alone a considerable amount of current is required to heat up the oven from cold. If, on the other hand, warm water or hot gas from the central boiler is allowed to circulate round the oven it keeps the interior at a temperature high enough for the oven to be used at any time as a hot cupboard for warming plates or keeping dishes hot. Then, when the oven is wanted for baking or roasting, a comparatively small amount of electricity is enough to raise the temperature quickly to the required degree.

No convenient name has yet been given to this union of central heating and electricity, but we can express its practical effect very simply by saying that it leads to a one-fire house. This one fire, it should be noted, is smokeless, and therefore innocent of one great fault of the coal fire. It can be placed in a scullery or basement where the slight amount of dust it causes will not affect the living rooms and where the heat it radiates will not be an oppressive nuisance in warm weather. As we shall see later, the adoption of the one-fire system with electricity for additional heating enables a house to be built on a much simpler and cheaper plan than is possible on the one-fire one-room system.

The electric fire and the electric water heater represent the main uses of electric heat in the home, but they are far from exhausting the catalogue of applications. As electric heating elements can be made in every variety of size and form, and as all they need is to be connected up by a flexible wire to a lamp-holder or wall-plug, they can be very conveniently applied to articles which are not readily heated by any other means.

Chief among these articles, in its appeal to the housewife, is the flat-iron. There is no need to dilate on the drawbacks of the ordinary flat-iron—its habit of being either too hot or too cold; its tendency to get rusty or dirty; the trouble it involves in going backwards and forwards to the fire; the heat and labour of using it. These are only too well known. And the virtues of the electric iron can be summed up in the statement that it has none of these drawbacks. The heating element is inside the base of the iron and is so designed that it keeps the iron continuously at the right temperature all the time it is being used. The surface is heavily nickel-plated



The electric iron is a boon which every housewife welcomes. On the right-hand side is shown the heating element, which is fixed inside the iron, and gives a uniform distribution of heat.

and therefore always clean. Moreover, the bright surface does not radiate heat after the manner of the black surface of the ordinary iron; thus the iron keeps hot and the ironer keeps cool. Within a minute or two of switching-on, the iron is ready for work, and the ironer can go ahead without interruption, finishing a batch of ironing in the shortest possible time. Being highly polished and always at the right heat, the electric iron does not need to be banged or pressed hard on the fabric to do its work properly; in fact, it is the one iron which can be efficiently used while the ironer is seated. The current consumed is very moderate, being less than half a unit per hour in the ordinary domestic size; but even if the cost

of using it were higher, any housewife who has once enjoyed its convenience and perfection of work, especially on dainty fabrics so often ruined by other kinds of ironing, would not hesitate to use it freely.

Several forms of electric heating appliance have been designed for use in the bedroom. They have one feature in common—that they use very little electricity. Perhaps the most familiar one is the curling-tong heater, a short tube-shaped appliance into which the tongs are thrust. Another not so well known is the electric comb, which is of metal and is gently warmed by electricity; it is used to dry the hair after shampooing. A more effective form of hair-dryer is a combined electric fan and heater which produces a current of warm air. The electric bed-warmer belongs to a group in which the wire forming the heating element is woven in with asbestos, making a flat flexible appliance. A very small amount of current is needed to make this appliance effective as a bed-warmer or for applying to the skin in case of neuralgia or any other local pain which can be relieved by heat. In order to prevent the appliance becoming too hot (as it would if covered up by bed-clothes for a prolonged period) a simple attachment is provided to cut off the current when the temperature of the pad rises above a certain point.

Woven electric heating elements can also be applied to blankets and bed-quilts for use in cases of illness or extreme cold. The heat produced is very slight, but it is applied uniformly all over the fabric, making it an infallible preventive of chills. Elements of this type are used to make warm gloves and boots and waistcoats for airmen. An astonishingly small amount of heat applied by this electrical means to the extremities will maintain a healthy circulation of the blood even in the most extreme cold. Electrically heated carpets have been made on the same principle, and suggestions have been put forward that they provide an excellent way of warming a room. While an electric fire warms by radiation from a small source at a high temperature, an electric carpet warms by providing a very large surface at a low temperature.

There are hygienic objections to using a carpet as a source of warmth, and some engineers have therefore put forward

the alternative of placing on window ledges and round the walls electric heating elements with a large area but run at a moderate heat. These suggestions, however, are not easily carried out in the ordinary house, and probably the most convenient form of low-temperature electric heater is the one built like an ordinary hot water "radiator." It contains only a small quantity of water, which is vaporised by a little electric heating element. The vapour rises and warms the appliance, which in turn warms the air ; and in losing its heat the vapour condenses into water which trickles down to the electric heater and is again vaporised. This method of heating is admirably adapted for keeping towel rails warm.

A word may be said here on the electric bath, although it is more generally looked upon as an electro-medical appliance than as one for domestic use. It is a "dry" bath, and consists simply of a cabinet containing a number of electric lamps. The user sits in the cabinet which, when closed, leaves only the head outside ; all the rest of the body is exposed to the warm rays of the lamps. In course of time a profuse perspiration is induced, giving the cleansing effect of a Turkish bath. People who have made their first acquaintance with the electric bath in connection with treatment for rheumatism assert that it is much less enervating than a bath in hot water and just as effective in keeping the body clean and healthy. It is possible, therefore, that electric heat may dispute the supremacy of soap and water as agents of cleanliness.

The industrial applications of electric heat are very numerous and are becoming more numerous every day. They can be divided into three classes, only one of which is on the same lines as the domestic applications we have been discussing. The other two relate to electric furnaces and electric welding.

Anyone who has been in the projector room at a kinematograph theatre will have keen recollections of the intense heat given out by the electric arc. And he will readily understand that if "electrodes" several inches square are used in place of the pencils of carbon, and if heavier currents are employed, the electric arc may become a furnace capable of melting the most refractory substances. There is, in short, no spot on

earth so hot as the centre of an electric arc. Extremely high temperatures can also be obtained by passing heavy currents through the materials it is desired to melt; the resistance offered by the materials converts the electrical energy into heat which melts them.

More than one great industry has arisen out of these facts. Aluminium, the light but strong metal which enters into the construction of such diverse things as pots and pans and airships, is produced by the melting and electrical treatment of clay in the electric furnace. Calcium carbide, which when moistened produces acetylene gas, is manufactured from lime and coke in the electric furnace. The hardest substances in the world (excepting the diamond) are the "artificial abrasives" used for grinding iron and steel; they also are produced in electric furnaces. The finest graphite, which forms the basis of one of the most efficient lubricants, is made by fusing coke or anthracite in the electric furnace. Most important of all, however, are the special steels. Whenever a steel of the highest quality is required, the electric furnace will produce it with greater certainty than any other.

This superiority is due to several factors. In the first place, the electric furnace is totally enclosed, and no air or furnace gases (which are inevitable where a flame is the source of heat) interfere with the chemical composition of the iron and other materials employed. Again, the temperature can be very accurately determined and very rapidly controlled. Extremely high temperatures, moreover, can be obtained with unparalleled facility. Electric furnaces are also coming into use for melting brass, where their advantages are that less of the zinc is lost in melting and the quality of the metal is better than is produced in any other type of furnace.

On a smaller scale, electric furnaces are used for hardening and tempering steel. Perfection in this process depends on precision of temperature control, which is the distinguishing feature of the electrical method. Here the resistance type of furnace is used. There is one ingenious form in which changes in the magnetic condition of steel at certain critical temperatures are made to provide an automatic signal.

Electric welding was one of the earliest applications of electric heat, and of late years it has been developed on a very ambitious scale. In order to weld two pieces of metal together it is necessary to bring the metal at the junction to a molten, or at least a plastic, condition, so that the pieces will flow together. To do this electrically all that is needed is to pass an electric current across the junction. Owing to the resistance offered to the electric current at the point of contact, heat is generated and rapidly brings the metal to melting-point. Another method of welding is to melt the metal in the heat of an electric arc : and one can readily see that if an iron or steel " electrode " is used instead of a carbon pencil, the electrode will melt away and feed metal into the junction.

The first, or resistance, method of welding is used in joining rods of metal or in closing the seams of thin sheets of iron or steel. Pots, pans, and other light vessels are rapidly completed by this process, which was also adopted in the production of the " tin hats " so familiar during the recent War. Continuous seams are made by effecting a series of overlapping local or " spot " welds between two jaws which squeeze the plastic metal and make a firm junction. The machinery for this purpose is almost automatic in its action and does its work with both speed and perfection.

" Arc " welding is adopted for all heavy work. It is an admirable substitute for riveting, and has been so used not only in making such things as steel tanks but also in building ships and in erecting steel structures. Riveting requires the drilling of many holes accurately in position, the use of additional pieces of steel to form bonds between the parts to be joined, and a considerable amount of labour in heating and hammering home the rivets. With electric arc welding all these complex processes are replaced by the simple action of holding a steel electrode close to the join and allowing the molten metal to unite the two parts with a continuous bridge of steel.

During the War a 1000-ton barge was built with an electrically welded hull and gave most satisfactory service. Official recognition was given to the electrically welded ship soon after the War by Lloyd's, and there is little doubt that in future the saving of time, material, and labour effected by welding will

lead to a great extension of its use in shipbuilding. The first tests which were made with electric welding in structural steel work during 1920 and 1921 were also most promising. Several factory roofs were erected without rivets, all the joints being made by welding on the site.

In the repair of worn or damaged parts of machinery, electric arc welding gives unrivalled facilities. It enables metal to be added so as to bring the parts back to their original size. Take, for example, the case of the crank axle of a motor-car, which is so worn that it is ready for the scrap heap. After steel has been welded on to the worn parts, the axle can be turned up again in a lathe and becomes as good as new. Again, take the case of a steel wheel whose spokes have begun to show fine cracks due to persistent road shocks. These cracks can be opened out by an electric arc modified for cutting purposes, and the cavities then filled in by means of a welding arc. Here it may be mentioned that by using special alloy electrodes any grade of steel can be provided in a weld. Even the tip of a high-speed cutting tool, which is made of exceptionally hard and tough steel, can be repaired by electric welding.

The third class of industrial applications of electric heat covers a very wide range of miscellaneous processes, and all that one can do here is to give a few illustrations. Wherever it is desired to apply pure heat, free from flame or fume, locally or to a moving part, the electrical method meets the situation in a way that no other can approach. For example, in stamping celluloid articles it is necessary to warm the dies and at the same time to avoid setting the celluloid on fire. A small electric heating element in the die meets the case to perfection.

Perhaps the most striking illustration of the flexibility of electric heating is afforded by a machine for tempering wire. The process involves heating the wire and "quenching" it in oil twice over, the first time to harden it and the second time to give the necessary temper. In each step it is vitally important that the temperature to which the wire is raised should be exactly right. This is done electrically by using the wire itself as a heating element. The heat produced depends on the

strength of the current passing through the wire, so that by regulating the current any desired temperature can be accurately obtained. Moreover, the heated portion of the wire is enclosed in a narrow tube which prevents the wire scaling and becoming discoloured as it would be if exposed in a hot state to the air. The process is continuous, the wire passing from the first heating section through an oil bath to the second heating section and thence to the final oil bath from which it emerges bright and perfectly tempered. An interesting feature of the equipment is that if any part of the wire has been drawn too thick or too thin, the electrical instruments reveal the fact and so prevent time and labour being wasted on imperfect material.

Many industrial processes require that articles should be dried or kept at a certain temperature for a period, or otherwise subjected to a carefully controlled degree of heat. In such cases electric heating is usually employed. It has the advantage that the heat can be applied anywhere and in any degree, and that it involves no complications in the way of flues to carry off waste gases. The japanning oven is a typical example of this group. Where an even temperature has to be maintained—as in an incubator for chickens or premature babies, or in the “culture” of bacteria—“thermostatic control” is employed. By means of a simple appliance the current is switched off when the temperature rises beyond a certain limit and is switched on again when the temperature falls below another fixed limit.

Electric heating is also largely employed in chemical processes where it is necessary, for example, to distil liquids (and especially inflammable liquids) at a carefully regulated temperature. Here the absence of flame and the perfect control of the heat are paramount advantages. In addition to these special applications there is a range of standard industrial heating appliances such as glue-pots, soldering irons, branding irons, and sealing-wax heaters. With all their differences in construction and purpose they all exemplify the special features of electric heating—the facility with which the desired degree of heat can be obtained at the particular spot where it is wanted. The actual cost of providing heat electrically in comparison

with other ways hardly enters into the calculation. Generally the amount of heat required is small. In some instances, electric heating is the only form permissible, and in all the others the secondary benefits of using it are so great as to make the question of prime cost negligible.

CHAPTER X

ELECTRIC COOKING

ALTHOUGH electric cooking is, strictly speaking, merely a branch of electric heating, it deserves a chapter to itself. The health and happiness of the human race depend very largely on the art of cooking. Moreover, electric cooking illustrates in a very high degree the qualities which make the electric way of doing things the best in the long run.

The first oven was a hole in the ground. It is represented to-day in the simplest form of "field kitchen" used by an army on the march. A hole is dug, covered over, filled with wood and provided with a vent at one side and an opening at the other. After the wood has burned itself out and the walls of the hole have become very hot, the ashes are withdrawn and the joints, loaves, and other things are inserted. All the cooking is done by the "residual heat" in the walls of the oven.

Given an ample supply of wood at a low price, this primitive oven probably still affords the cheapest means of roasting and baking. It is, however, very inefficient, since much heat escapes by the vent and a large amount is lost in merely warming the surrounding soil. The inconveniences of the arrangement are manifest, but the main drawback is the total lack of control over the heat. To place a mixed batch of food in such an oven, and to expect every item to come out properly cooked, is almost an act of faith.

The ordinary domestic oven is, of course, an improvement on this survival of barbarism. Nevertheless, it bears a strong resemblance to the original hole in the ground. It is placed at much the same level. It involves the waste of a large amount

of heat up the flue and also the warming of a large mass of material—in this case cast iron—in order to convey heat to a joint or a loaf. Further, the control of the heat is far from perfect. Even when the wind is in the right quarter, when the flues are clean, and the coal is of good quality, great skill and constant attention on the part of the cook are needed to regulate the temperature so that it is not too high or too low at any stage. The phrase, “God sends food and the devil sends cooks,” is a proverbial way of emphasising the extreme difficulty of getting a coal range to do its work properly. Indeed, on certain points, the best cook in the world cannot make this appliance obey the laws of good cooking.

It is worth while considering, therefore, exactly what we want to do in cooking a joint to perfection. The first step is to seal up the pores of the meat so as to retain the juices. The second is to allow heat to permeate the meat so that it is cooked right through, but without burning or drying up the outer layers. The third is to impart to the outside, and especially the fat portions, that crispness which makes the joint appetising both in appearance and in reality.

Now, it is clearly impossible to get these effects with a coal oven. The first step requires a very high temperature to sear the outside of the meat; the second involves a rapid drop to a low temperature steadily maintained for a long period; and the third requires a sudden rise for a few minutes. Such rapid changes cannot be made while one is depending on the heat given off by a coal fire and large masses of iron. Whatever changes can be obtained by manipulation of dampers must be slow—too slow for the best results. Something much more flexible is called for if cooking is to become what it ought to be—a branch of applied science. And flexibility, as we have already learned in connection with electric fires, is characteristic of electric heating.

The electric oven consists essentially of a metal box containing electric heating elements. There is no flue, and therefore none of the heat given off by the elements is wasted in a draught which draws in cold air and gives out hot air. The walls of the oven can be made of light steel, thus avoiding the necessity—in other ovens—of heating up thick masses of cast

iron. Usually the walls are double, consisting of two layers of metal with some heat insulating material in between—an arrangement which effectively imprisons the heat. In most cases the heating elements are ranged on the left and right hand sides of the oven—two, three, or four per side, according to the size of the oven. Each element can be separately controlled by switches fixed on the oven or on a wall-panel conveniently near. Simply by manipulating these switches the cook can secure any degree and distribution of heat required. On many makes of electric oven a thermometer is provided, forming a scientific substitute for the cook's hand as a means of discovering the temperature of the interior.

It is easy to see how readily an oven of this kind will meet the conditions set out as necessary to good cooking. By switching on full heat the oven is rapidly raised to the searing temperature ; and when the thermometer indicates the requisite degree the joint is put in. After a short interval to complete the searing process, some of the heaters are switched off and, as there are no large masses of iron with a lot of residual heat, the temperature of the oven falls fairly quickly to the degree suited to the second stage, that of slow cooking. The oven can then be left to get on with its work until a few minutes before the time of serving. Then all the heaters are switched on to give a final rally, and the process of cooking is completed.

Turning to the question of cost we may point out first of all that very little of the heat given off by the elements is wasted and that for the greater part of the total time of cooking the oven is at low heat. But economy, as we have seen in the case of lighting and heating, must be judged in the light of all the conditions and all the results, secondary as well as primary.

If electric cooking is more exact and scientific—if, that is to say, it enables even an amateur cook to be sure of getting good results, not once but every time—it will prevent food being spoiled and will therefore save money even though the actual cost of cooking by electricity were greater than cooking by fuel.

Again, if electrically cooked food is more appetising and more digestible than food cooked otherwise, we get a gain in health which would be worth paying for. A third advantage

is the saving in trouble and temper. For the greater part of the cooking period the cook need not be near the oven ; at no time is there any necessity to be opening the oven door to see how the joint is " getting on." The whole duty of the cook is to touch a few switches at certain intervals.

Over and above these benefits, however, there is one which has an important money value. Every cook knows that a joint shrinks in cooking, but few realise how much of the original weight of the joint is lost in the process. It is quite an education in the waste of ordinary cooking to weigh a joint before it goes into the oven and after it comes out. Anything up to a quarter and more of the weight of the meat paid for has disappeared. The famous Mrs. Beeton gave the figures at one quarter to one third. This loss is due to the fact that during the second stage in cooking the heat of the oven has been so great (owing to the lack of control) that in penetrating to the interior of the joint it has shrivelled up the outside layers. With electric cooking, where the temperature in the second stage is kept at the proper level, there is much less shrivelling, and with a little care in switching down at the right time the joint when served need not have lost as much as one-tenth of its original weight. A skilful cook can bring the percentage of loss down to three. Obviously the real cost of a joint is price per pound put on the table, not put in the oven. And to save even a few ounces of meat in the process of cooking is to economise sufficiently to pay liberally for the cost of the electricity consumed.

Before showing that this economy in food is repeated with other electric cooking appliances, other incidental advantages of the electric oven may be mentioned. One is that the oven—at any rate when it is of the light sheet-steel form described—can be placed on a table or stand at a convenient height, thus making a final departure from the ancient tradition of the " hole in the ground." Another is that so little heat escapes from the oven by radiation or otherwise that the kitchen does not become overheated—one of the causes of the bad temper from which cooks so often suffer. Again, electric heat is pure heat ; there are no fumes to spoil the flavour of dishes or to make the atmosphere of the kitchen unhealthy. It is not

generally known that fat has a wonderful power of absorbing vapours. In chemical processes it is used for that purpose ; and when roasting fat is exposed to a stream of fumes there is bound to be absorption, with no benefit to either the palate or the digestive organs.

In baking bread and cakes and in making pastry the ease and certainty with which the temperature of the electric oven can be controlled are invaluable. Every baking recipe in the cookery book has instructions about the proper heat of the oven, but the cook needs to be an expert stoker and to possess a thermometric hand before she can be at all sure that she has got the conditions right. There is no need to dwell on the uncertainties of loaves and cakes and pies ; they have passed into the current humour of the people. Cookery in the ordinary way is a " hit and miss " process ; it is to some degree a matter of chance even when the cook is intelligent and takes care. By using the electric oven for baking purposes the cook can rely upon getting the best results if she follows a few simple directions. And she can be sure of repeating these results as often as she pleases. This advantage was put to good use by a wholesale flour merchant who invariably used an electric oven for baking sample loaves ; he found that the loaves would always show the quality of the flour to the best possible advantage. Here again we may emphasise that the electric oven, by insuring against the waste of food and by enabling even amateur cooks to produce perfectly cooked dishes, has merits which put the question of the prime cost of cooking by electricity far into the background.

When we come to the use of a boiling plate a similar situation holds. Electricity may not provide the cheapest means of raising a quart of water to the boiling-point, but the electric " hot plate," as it is usually called, brings its train of secondary benefits in stewing fruit or meat and in cooking various dishes. The final result is so good that the cook who has once experienced it will never be content with any less simple and scientific a method.

Of all dishes in common use meat stews are most frequently spoiled by bad cooking, and for the reason that with ordinary cooking appliances it is very difficult to maintain the tempera-

ture at the right level. The albumen in flesh and fowl coagulates when it is kept at the temperature of boiling water for more than a minute or two : and in coagulating it makes the meat tough, rendering it not only unappetising but indigestible. Therefore in cooking stews, and in casserole cooking generally it is vitally important that the dish shall simmer gently without coming to the boil or sinking below the degree of heat required for cooking. With other than electric cooking the cook has to be constantly on the alert ; as soon as her back is turned the source of heat is certain to play tricks and ruin the dish. On the electric hot plate, however, the lowest heat is designed to give the exact conditions required for simmering. Having "switched down" to that heat the cook can leave the dish without supervision, because the temperature is steadily maintained. Perfect results then depend simply on the time allowed.

On this ground alone electricity would be ideal for casserole cooking, but the electric hot plate has a further quality which is of value not only in stewing, but in making jams and other preserves. In the electric hot plate the heating element is so arranged that it provides a uniformly heated surface. There are no extra hot places surrounded by comparatively cool places. Thus the heat is conveyed evenly to all parts of the dish, local over-heating of solid portions in contact with the bottom of the dish is prevented, and the setting up of strong convection currents, which constantly agitate the contents, is avoided. The conditions are, in fact, similar to those obtained in paper-bag cookery or in hay-box cookers, and the inconveniences of both these methods are not incurred.

In making stews the uniform heating and absence of agitation keep the tissues of vegetables intact and preserve their full flavour. Every cook is familiar with the difference between apples stewed in a saucepan over the fire and done in the oven. The point we seek to emphasise is that the electric hot plate reproduces the effect of the oven treatment, preventing the fruit falling to pieces and losing its flavour. Not only is the fruit better cooked, but there is in the end *more of it*, since the tissues do not disintegrate. This feature is conspicuous in making jams, marmalade, and other preserves. It is an

ascertained fact that so many pounds of fruit and sugar will produce more jam with electric cooking than by any other process. Moreover, the harder tissues, such as the peel in



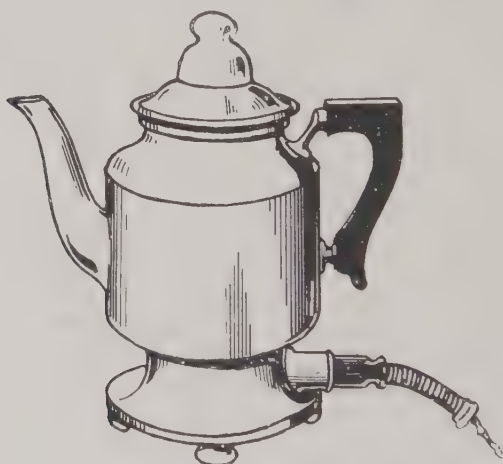
TWO APPLIANCES SUITABLE FOR TABLE COOKERY

The electric hot plate and the electric chafing-dish.

marmalade, are more tender and of better flavour than is usually the case.

Grilling illustrates in a similar way the perfection and

simplicity of electric cooking. It is almost impossible, apart from electricity, to obtain and maintain the exact degree of radiant heat required for correct grilling. The electric grill consists of an open heating element which throws its heat downwards on a grid or dish which can be raised or lowered. Every part of the dish receives the same amount of heat, and by adjusting its position the precise condition for the correct grilling of different things can be secured. Once more we see how electric cooking gives absolute control, enabling the least efficient cook to be sure of obtaining the best results every

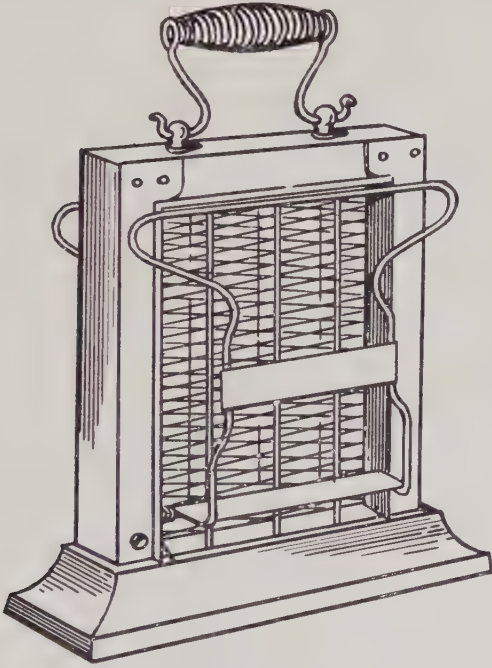


THE ELECTRIC COFFEE PERCOLATOR

Makes excellent coffee with the minimum of trouble.

time. In grilling steaks and chops the evenness and correct intensity of the electric heat ensure that the surface of the meat is uniformly seared, thus retaining the juices and reducing the waste in the process of cooking. No contamination of the food takes place, as there are no fumes given off by the electric grill. Flavour and digestibility are thus improved, and the fat collected is clear and pure. With ordinary methods of grilling, the fat is wasted and is the cause of objectionable smells. A restaurant which adopted electricity for grilling obtained enough money from the fat to more than pay for all the electric current used by the grill.

The elements of cleanliness and purity in electric cooking are not only important in the kitchen, but have led to the use of electric appliances for "table cookery." There is no objection to an electric grill, or hot plate, or chafing dish, any more than to an electric kettle, being placed on the table. This is a great convenience for those who have to cook their own breakfasts or in preparing a light supper after servants'



ELECTRIC TOASTER

Toasts two pieces of bread simultaneously. Like many electric cooking appliances, this can be used on the table.

hours. In America, where ladies are peculiarly fond of making fancy dishes for their own delight, table cookery is more common than it is here, but the fact that it can be carried out with electrical apparatus, and in safety with electrical apparatus alone, is a striking illustration of the hygienic advantages of electric cooking.

An incidental word may be said upon one electrical appliance

for table use which exemplifies how easily the best results are secured when electricity is employed. Coffee is made badly more often than it is made well, because it requires a measure of care which most people are too casual or impatient to give. With the electric coffee percolator perfect coffee is made almost automatically. The coffee is placed in the upper portion of the appliance, and water in the lower ; current is switched on and the water is gradually heated until it boils, ascends a tube and bubbles over on to the coffee, through which it percolates. After switching on the current, no attention is needed until the coffee is ready. The process always occupies the same time, so that one can place the percolator ready on the dinner table and switch on at a certain moment, knowing that after a fixed period perfectly made coffee will be ready for serving.

One of the most popular of electric table appliances is the electric toaster. It consists of a grid-like electric heater, fixed upright on a stand which is fitted with clips for holding a piece of bread close to either side of the heater. The even radiant heat quickly toasts the bread to a crisp golden-brown—the ideal at which the toast-maker always aims and so often misses. In some forms the upper part of the appliance is flat, so that pieces of toast can be placed on it to keep hot. For those who like muffins or crumpets well toasted and piping hot, this little appliance, which takes a trifling amount of current, is an obvious boon. Like everything electrical it is always ready at the touch of a switch and does its work to perfection with a maximum of convenience.

The ordinary electric cooking range for domestic use consists of an oven, a grill, and one or more hot plates. By increasing the size of the oven and multiplying the number of hot plates, the requirements of larger houses can be met. The Engineering Standards Association has standardised two sizes of electric oven, one with a cooking space of 18 inches (height) by 13 inches (depth) by 14 inches (width), and another measuring 21, 15, and 16 inches. The switches controlling the various heating elements are usually placed on a panel upon the wall behind the range, and each switch is fitted with

a small pilot lamp which reveals whether the corresponding circuit is "on" or "off."

Large electric cooking outfits for restaurants and works' canteens are constructed on broadly similar lines. During the War many canteens in munition works were equipped electrically, greatly to the benefit of the employees. In a textile mill it was found that the provision of electrically cooked meals materially increased the output of the workers,



ELECTRIC TABLE COOKERY

The appliances here shown on the table include a grill, kettle, dish-warmer, milk-warmer, toaster, and coffee percolator.

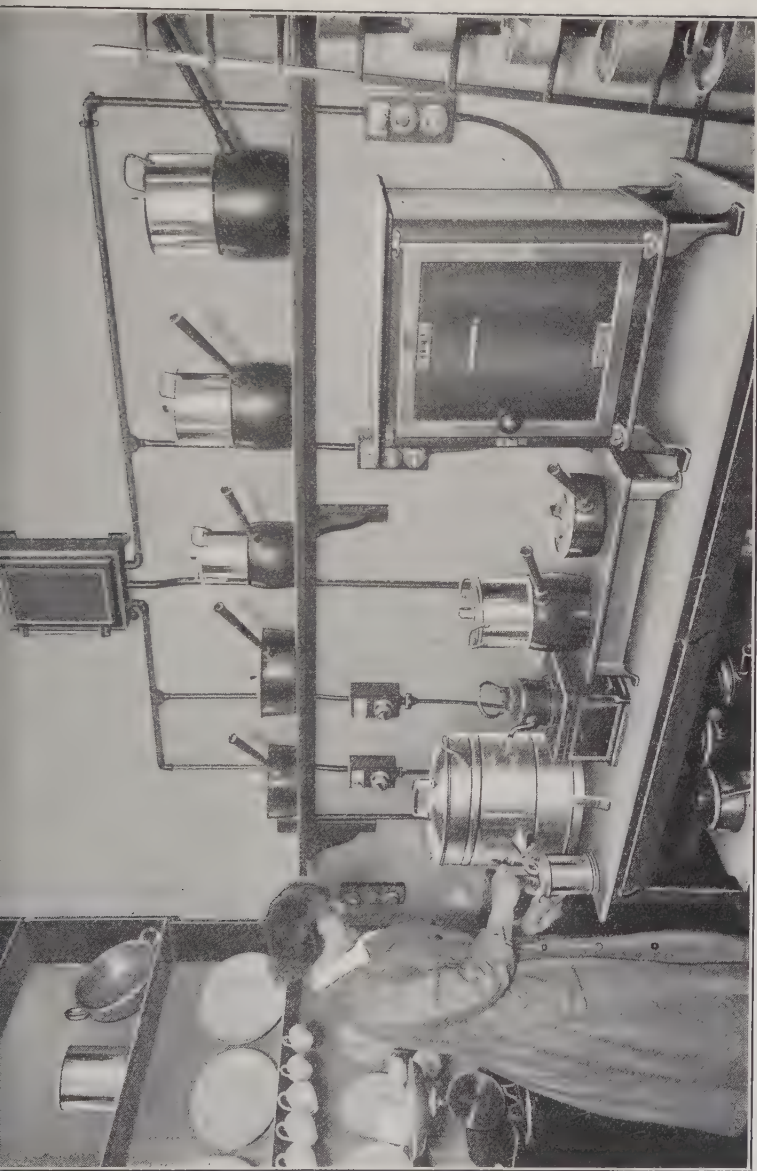
who had previously depended upon supplies from home or from local cook-shops. Being fed more wholesomely they worked better without increased effort. The firm supplied the meals practically at the cost of the food and the cooking, so that the gain in output represented a very handsome return upon the investment in electric cooking appliances.

Anyone who has electric light installed in his house can make a preliminary trial with electric cooking at a small cost. There are available small radiant "hot plates" which take

so little current that they can be run off the electric light circuits ; yet they are capable of frying bacon and other things, and of boiling water. It is more satisfactory, however, to run a special circuit to a convenient point in the kitchen and use an appliance such as a breakfast cooker on which meals for several people can be more conveniently prepared. A complete electric cooking equipment can be built up by separate appliances - grill, oven, hot plate, frying pan, and so on. In the case of saucepans, fish kettles, and frying pans, ordinary utensils can be used on the electric hot plate, but it is more efficient to fit each article with its own electric heater, so as to make it a self-contained electric cooker. The bottom of an ordinary pot or pan is rarely flat enough to make good contact all over with the surface of a hot plate ; and unless the contact is really good the heat does not pass quickly from the hot plate to the utensil. Consequently utensils supplied for use with electric cookers are specially ground to give a surface which fits close on to the hot plate.

In the self-contained electric cooking appliance the heater forms an integral part of the base and conveys its heat almost directly and with very slight loss to the contents. The initial cost of such appliances is, however, rather formidable if one sets out to acquire a full range of them ; and designers have sought in other directions to combine efficiency with cheapness in first cost. Some of them have introduced an electric hot plate with open elements which, when the full current is switched on, glow at a bright red and transfer their heat by radiation to any utensil placed over them. Still higher efficiency is secured by using an " immersion " heater of the type already mentioned in connection with warming large quantities of water. As the heater is wholly surrounded by water, none of the heat is lost. Ordinary pots and pans can be retained with this " 100 per cent efficiency " method of heating, and as one heater will do for any number of utensils in succession the initial expense is not so heavy as when each utensil is fitted with its own fixed heater.

There is one condition of success in electric cooking which deserves to be emphasised. Most people are attracted to electric cooking by its cleanliness, convenience, and other more or



STANDARD ELECTRIC COOKING OUTFIT FOR THE HOME

This includes an oven, a double boiling plate, a grill, and a water heater. Each piece of apparatus is controlled by switches on the wall. It should be noted that everything stands on a table at a convenient height.

less obvious qualities. But the essence of electric cooking is *control*—the perfect, easy control of heat in the oven, grill, hot plate or other appliance, simply by the operation of switches. And unless this control is properly used, electric cooking will not give the best results.

Nothing could be easier than to use this control properly. The cook has before her a row of switches, each controlling its own part of the equipment and giving full heat, half heat, low heat, or no current, at the turn of a knob. Compared with a coal range or any other non-electric cooker, the control is child's-play. Nevertheless, habit is so strong that many cooks follow the old way with the new cooker. When a pot boils over, they move it to one side, instead of switching the hot plate down to half heat or low heat. When the oven gets too hot, they open the door instead of switching off one or two of the elements. In these and other ways they waste heat ; and in wasting heat they waste electricity and run up large bills for current. Moreover, they spoil food by not obeying the simple directions which will ensure the correct temperature at every stage in the process of cooking.

Perhaps the most outrageous case of misuse of electric cooking apparatus was where a cook had a habit of switching everything full on and leaving the oven door wide open in order to warm the kitchen. But apart from such eccentricities there is a real need to impress upon the cook that the electric cooker is *something different* and should be treated accordingly. Once acquired, the habit of switching on and off becomes almost automatic ; it is, however, something new to most cooks and therefore calls for the exercise of will and intelligence. The inertia of the domestic mind shows itself in many ways—in a pig-headed preference for the laborious knife-board in place of easy knife-machines, in trotting backwards and forwards with handfuls of dishes when one journey with a tray will suffice, and in a general attitude of hostility towards everything new, even when it saves work. Patient instruction and demonstration are thus needed to make the average cook get the best out of electric cooking. Even the intelligent housewife, we imagine, will take a little time to realise that cooking is really a science and that it is as necessary to be as careful about the

heat control of the cooker as about the proportions of the ingredients in the dish. Cooking has been a hit-and-miss game for so many generations that the feminine mind is not prepared to appreciate that by using an electric cooker and following a few easy rules an indifferent cook can obtain, not once but always, a high level of perfection with the fullest economy in food and in electricity.

CHAPTER XI

THE LABOUR-SAVING HOME

THE domestic uses of electricity already described—electric light, electric heating and electric cooking—are all labour-savers. Electric light is instantly available at any time of day or night simply by touching a switch and if the switches are conveniently placed the trouble even of walking a few yards to turn on the light is reduced to the minimum. The lamps and fittings themselves require no more than occasional dusting, and washing at longer intervals. Ceilings, decorations, and silver articles are not tarnished by electric light and therefore do not call for frequent cleaning.

Electric heating not only provides a means of obtaining pure heat in any room at any moment, but it obviates the labour of laying and lighting and tending coal fires. Coal fires, again, are the most fertile sources of dust. Electric cooking calls for nothing more formidable than the turning of a few switches at certain times; the ovens and other appliances are always ready; and they can be kept clean with a minimum of trouble.

So, without going beyond lighting, heating, and cooking, electricity confers a great boon on the overburdened housewife. It does so by transferring from the home to the central station the work connected with preparing the means of illumination and with the burning of fuel. Instead of having to carry through a laborious series of operations, all that the housewife has to do is to touch a switch. Light, and heat for warming rooms and cooking food, come to her "by wire."

If this were all the service rendered, electricity would still be entitled to a high place in the attempted solutions of the domestic labour problem. During the last ten or twenty years this problem has become very serious, especially for families

with moderate means. Long before the War the proportion of women who were ready to go into domestic service was declining; the War swept a large number of actual and potential servants into munition factories and Government Departments; and since the War the hopes that most of these women would return to service have been only partly realised. The households which can claim to have one, two, or more really competent servants under their roofs are in the minority. Most people, apart from those able to pay high wages and offer very easy conditions, have to make the best of more or less incompetent help for a limited number of hours each day. In short, the demand for domestic servants is far in excess of the supply and seems likely to remain so.

It is our national habit to turn everyday troubles of this kind into a subject of humour, but the fun of the domestic servant problem is decidedly mixed. Thousands and thousands of women are confronted with the almost impossible task of simultaneously doing the work, or most of the work, in their homes and of bringing up a family. Being able to pick and choose, the modern domestic servant selects the houses where there are no children with the result that the homes which need most help are those most often deprived of it. The effect of this condition of things on the health and well-being of the people, and on the growth of a better-grade population, need not be emphasised. There is as much agreement about the seriousness of the situation as there is divergence of opinion about the way in which it can be improved.

Here and there one comes across optimistic people who hope that matters will revert to the good old days when one could actually make a cool decision between half a dozen applicants for a coveted domestic post. These sanguine souls delude themselves. We may as well admit that domestic life in the nineteenth century was based on conditions which will never recur. Population was then pressing hard on the limits of subsistence; very few avenues of work were open to young women of the lower classes; the ambitions of these women looked little higher than security for subsistence and the prospect of early matrimony. In those days mistresses conferred a boon on girls by offering them a home, with work to

occupy them from six in the morning till ten at night, and with a few hours a week of carefully supervised freedom. Bearing in mind the long hours, the monotony, the restrictions, and all the other elements of slavery, it seems remarkable that so many tens of thousands of women were ready to embrace domestic service. Necessity, no doubt, was their counsellor.

Their willingness to submit was clearly reflected in architecture and in furnishing. The basement kitchen is a monument to the domestic servant, now almost departed. The building of houses of several stories with two or three women available to run up and down stairs an incredible number of times from cock-crow to curfew ; the all-covering carpets, the heavy furniture, the thick hangings, the infinitude of brass and iron and other metal articles to be perpetually polished : the whole apparatus of Victorian home life was devised to provide endless occupation for tireless maids. And it was quite in harmony with the spirit of the era that the service to these household gods should be rigorously exacted. The good mistress was she who overlooked nothing and did not hesitate to treat her maids with the licensed brutality of a sergeant-major. By one of the anomalies of human nature, this kind of mistress was the most admired and the most devotedly served.

There is no more likelihood of this domestic slavery being revived than there is of our reverting to the basement houses of the last century. The modern home, although far from the ideal, is built and furnished with some consideration for the work to be demanded from those who live in it and are expected to keep it habitable. We shall see later the influence which electricity may have on the design of houses, but for the moment we shall consider how its further use helps the housewife to carry on in a home not specifically designed for labour-saving. It is as well to remember that the vision of the ideal home must remain for the majority of folk a vision. The problem for most of us is to make the best of the homes bequeathed to us by previous generations.

Dust and dirt are the twin demons of the household. There are some women who take a perverted pleasure in exorcising them ; they dust, and scrub, and polish from morning till

night, year in and year out, with a religious enthusiasm. But for the normal housewife the perpetual struggle to keep a house clean is an unmitigated curse. And in its day-by-day phase it is a losing struggle. The institution of Spring Cleaning is a proof that for the rest of the year dirt has been gaining ground. A pitched battle, in which the house is gutted and domestic life reduced to a tragi-comic chaos, is necessary to achieve a decisive victory. But it is only a momentary victory. As soon as ordinary existence is resumed, dust begins to find its way back to its ancient territories.

The traditional method of "removing" dust is a model of inefficiency. It resembles the once prevalent way of dealing with tramps, who were simply moved from one parish to another and so kept in circulation with short intervals of unwelcome residence. When a carpet is swept some of the surface dust finds its way into the dust-pan, but much of it is whirled into the air and settles again on the carpet or on the walls or furniture. The dust which lies within the fabric is not disturbed at all. When upholstery is beaten or curtains shaken the superficial dust is "moved on" and drifts to another resting-place. The process of dusting furniture is equally barbaric, and the domestic tyrant who has the unpleasant habit of visiting the drawing-room half an hour after the dusting process and drawing her finger along the top of the grand piano may be showing her ignorance of the habits of dust as well as her knowledge of the ways of servants. Finally, the dust which is not within easy reach of brush or duster remains in peace and collects until the Spring Cleaning.

To those who love cleanliness, therefore, the old way of dealing with dust is love's labour lost. The monotony of the process might be forgiven if it were efficient, but to spend an hour or two each day in doing a job badly is to aggravate the burden of the necessity. Electricity, however, provides a means of actually removing dust with far less labour than is involved in the old-fashioned way of pretending to remove it. When the vacuum cleaner was first introduced, it was a formidable machine which was placed outside the house and did its work by the medium of long flexible pipes brought through windows or doorways. Such a visitation could be tolerated

only at Spring Cleaning or at rare intervals. It belonged to the pitched battle and not to the daily business of dusting.

The electric vacuum cleaner—or suction cleaner as it is more properly called—is a small appliance which weighs only a few pounds. It is, in effect, a portable domestic tool, consisting chiefly of an electric motor, a fan, and a dust-retaining bag. The motor, which is very small and takes only about a third of a unit of electricity in an hour, drives the fan at an extremely high speed and so causes a strong suction. Motor and fan are fitted inside a case with a flat nozzle at the lower side and an outlet to the dust-bag at the other; and when the nozzle is placed on a carpet or other fabric the suction draws all the dust out and passes it into the dust-bag, where it is collected and from which it can be emptied later into the dust-bin.

There are two things to be observed about this simple electric appliance. The first is that it can be used with practically no effort. It rests on small wheels (usually with ball-bearings) and by means of the handle attached it can be pushed up and down the carpet by a child. The second point is that it does its work with a Spring-Cleaning thoroughness. The effect of the suction is felt right through the carpet, as the air is drawn in from the lower side of the fabric; therefore the deep-seated as well as the surface dust is dislodged and captured. It is a proven fact that a carpet which is given a quick run-over once a day and a somewhat more careful treatment once a week is as free from dust at the end of years of use as it was on the day it was first laid. The suction, moreover, draws up the fibre of the carpet and keeps the nap in good condition, while the effect of ordinary sweeping is gradually to destroy the nap and make the carpet look worn before its time.

The efficacy of an electric suction cleaner can be very easily tested. Perhaps the most drastic way is to disconnect the dust-bag, so that the dust extracted by the fan is blown directly into the air and gives visible (and unbreathable) proof of the work which the suction is doing. A more pleasant way is to try the cleaner (having just emptied the bag) on a carpet which has been "cleaned" as well as possible by other means.



Diagrammatic view of the electric suction cleaner, showing the nozzle, the fan, and the dust-collecting bag.

After five or ten minutes of electric suction cleaning the carpet will probably be found to have yielded several ounces of dust.

It so happens that the cost of using the electric suction cleaner is trifling. The appliance can be run off any lamp-holder or wall-plug, so that no special wiring is needed, and it can be conveniently used in any room fitted with electric light. It is at work—so far as each room is concerned—for only a few minutes at a time ; and as it can be easily carried about, one machine is sufficient for quite a large house. But even if it cost much more in current and in incidental expenses than it actually does, it would be welcome for the labour and the time it saves, for its effect in prolonging the life of carpets, and for the hygienic and other value of the absolute cleanliness it produces. There is perhaps no single electric appliance which does more to relieve the overburdened housewife than the suction cleaner.

Its range of action, however, extends far beyond carpets. Every suction cleaner can be fitted with special attachments by which dust in any part of the room or the furniture can be eradicated. These attachments consist of nozzles of various forms connected up to the machine by means of lengths of rubber tubing extended, for certain purposes, by portions of aluminium pipe. The principle of action is the same in all cases ; the differences lie in the shapes of the nozzles. Some are adapted for upholstery and bedding, some for curtains or billiard cloths, others for walls, shelves, ledges, or cornices. In all cases their use is perfectly simple and their effect as thorough as in the case of a carpet. They enable every portion of a room to which access can be gained by a small nozzle to be made dust-free.

Another adaptation of the machine gets at the dust which is inaccessible in any other way except by moving furniture and other objects. Every suction cleaner can, by an easy adjustment, be made to give a blast of air ; and this blast, when passed through a small nozzle, is sufficiently concentrated to dislodge the dust that lurks under low cupboards, behind furniture, and in the recesses of book-cases and cabinets. The dust so disturbed does, of course, settle elsewhere in the room ; but the “ elsewhere ” is easily accessible to the suction cleaner.

By using the blowing action first and the suction action later, the whole room and its contents can be completely freed from dust without any of the usual laborious "turning out." Thus,



Electric vacuum cleaners can be used not only for carpets but, by means of simple attachments, for removing dust from upholstery, bedding, and curtains.

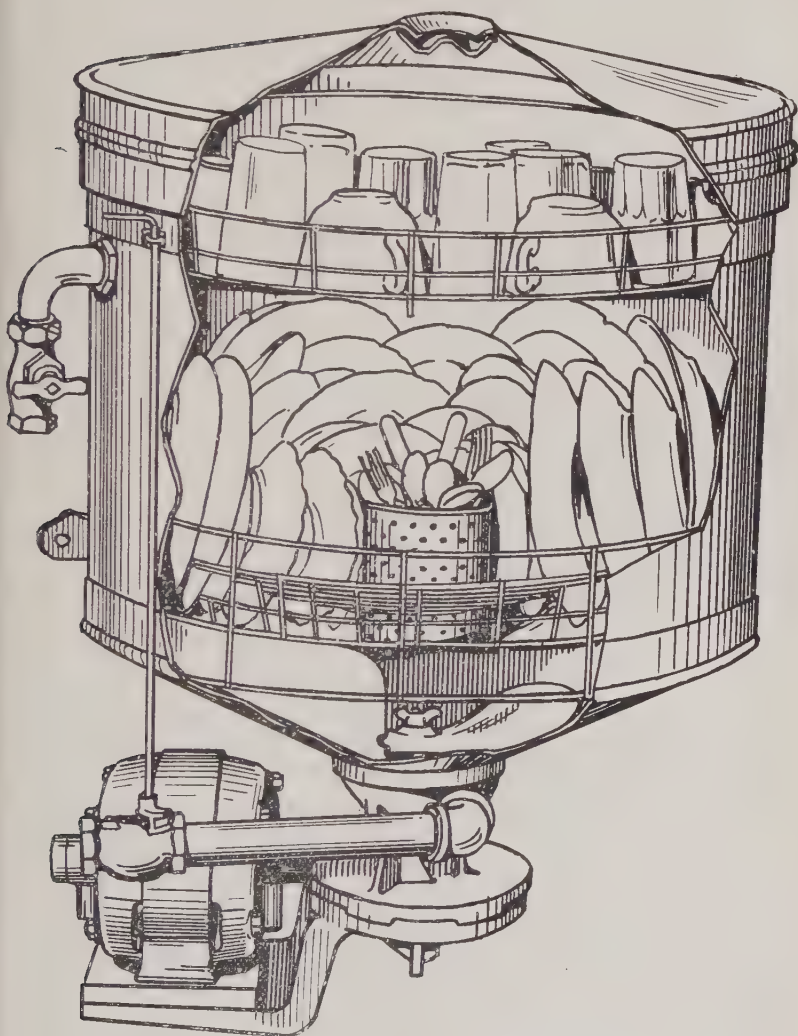
so far as dusting is concerned, a room can be spring-cleaned with a minimum of time and trouble.

The type of electric suction cleaner which we have described is the one in most common use for domestic purposes. There

are, however, other types which deserve to be mentioned. Some are made light and compact enough to be carried in one hand or slung over the shoulder—a form which is very convenient for dealing with curtains and chairs and also for book-cases. More powerful machines, suitable for hotel and office use, are made with the motor, fan, and dust receptacle in a cylindrical case on wheels. Long lengths of hose, to which nozzles are fitted, are supplied so that the contents of large rooms can be conveniently treated. Still another development is to place a powerful machine in the basement and have a permanent system of pipes leading to outlets in each room; the hose is then simply connected to the outlet. This arrangement is adapted to conditions in theatres, picture palaces, and other buildings where a large amount of cleaning has to be done rapidly, as it enables several hose and nozzle equipments to be at work in various places at the same time.

There is one field in which the electric suction cleaner has not deeply penetrated but in which its virtues should make it extremely welcome. Booksellers, stationers, fancy goods merchants, and many other tradesmen have to carry stock which is depreciated by dust; and in practically every shop, warehouse, and office the process of dusting is so laborious, and therefore so costly, that it is seldom carried out as often as it ought to be. The electric suction cleaner solves the problem in the most efficient way, because it routs out the hidden dust and then removes it rapidly from all the places where it is not hidden. Here, even more than in the domestic field, the advantages of the appliance are so great that even if it did not economise in labour and even if it did not cost little in electricity, it would still be a most profitable investment.

If there is one duty which the housewife detests more than another it is the washing of dishes. As generally performed, with (more or less) warm water, washing soda, and mops and dish-cloths, it is a messy barbarism. In the servantless house "washing up" presents itself as the most formidable item in the programme and one that volunteer help is most anxious to evade. In the house which is blessed with a servant, it is the process which leads to most recrimination, not so much because



THE ELECTRIC DISH WASHER

which cleans by sousing the dishes in streams of soapy or clean hot water,
pumped up by the electric motor at the base.

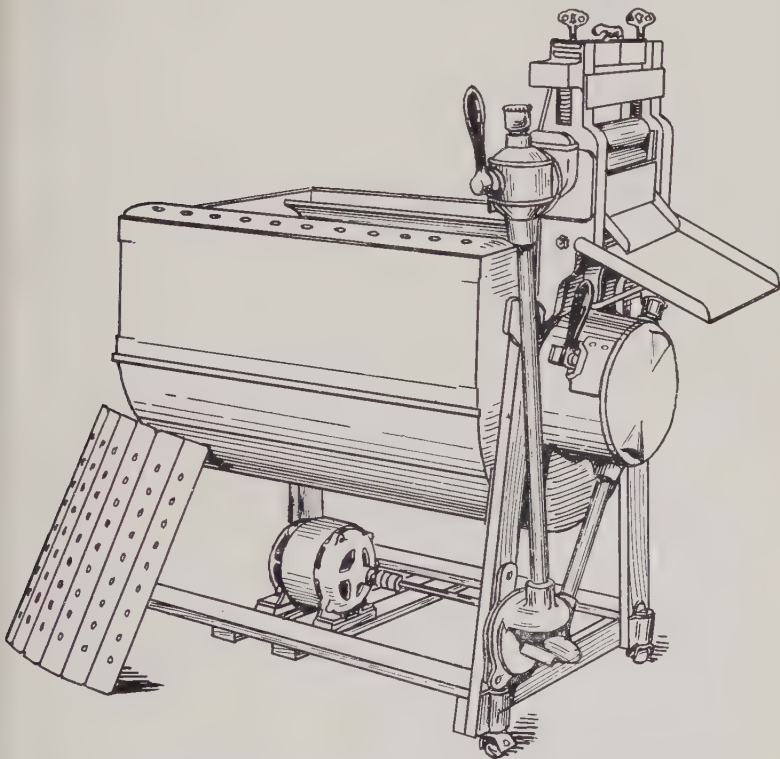
of its casualties in crockery as because it is something that must be done properly and is generally scamped.

It will come as a surprise to many people that electricity as electricity should be of any assistance in washing dishes. We have so long been accustomed to washing dishes plate by plate and cup by cup that the notion of cleaning them wholesale, as it were, by machinery, seems strange. Nevertheless, the electric dish-washer is simplicity itself. It takes a variety of forms in matters of detail, but the general design is almost always that of a small tank-like vessel fitted with an electrically driven pump. The dishes are placed on a wire tray and lowered into the vessel, which is then closed. Current is switched on to the electric motor driving the pump, which thoroughly souses the dishes in a maelstrom of hot soapy water. After this water has drained off, the process is repeated with clean hot water. Then the dishes are taken out and placed on a rack to dry.

The great feature of electric dish-washing is that so little work is involved. It is quite an easy matter to stack the dishes on the tray, to switch on the current, and later to place the dishes on the rack. All the hard work is done by the electric pump, which agitates the water so thoroughly that every part of every dish gets properly treated. Moreover, the water used can be very nearly at boiling-point. One of the many drawbacks of the old way of washing-up is that the water must not be any hotter than the hand can bear. At that temperature it is not hot enough to remove grease quickly and thoroughly—hence the necessity of using soda and of wiping each dish. In the electric dish-washer the water may be so hot that all grease is instantly removed; and consequently the dishes dry with the clear lustre of absolutely clean china. Another point of importance is that the dishes are actually sterilised. The treatment with very hot soapy water is fatal to organic impurities. With dishes washed in a bowl of water which gets cooler and greasier as the work proceeds, cleanliness is only a relative term.

As the electric pump is at work for only a few minutes for each washing-up, and as the motor is a very small one, the amount of electricity involved in electric dish-washing is really

trifling. A supply of very hot water is necessary, but the quantity required is not large, because the pump churns the same water continuously at each stage in the process. It is most convenient to fix the washer in connection with the hot water supply and the scullery drains, but the expense of this arrangement can be saved by using a wheeled machine which



COMBINED ELECTRIC CLOTHES WASHER AND WRINGER

All the hard work of washing is done by the small motor seen below the machine.

can be brought near a hot-water tap for filling and moved to a floor outlet for discharging.

Against any expense which the electric dish-washer involves we may place not only its labour-saving qualities and the swiftness of its work, but a material saving in breakages. It is in wiping the dishes and in handling them in a more or less

greasy condition that most of the casualties occur, especially with glass and delicate china. By reducing the amount of handling required the electric way reduces the risk of breakages. We may go so far as to say that the saving in breakages will contribute materially towards the cost of the appliance.

The electric clothes-washing machine is a more familiar piece of apparatus, but one whose virtues are not adequately realised in this country. It became popular in America as the easiest way of escape from laundries on the one hand, with their high charges and general destructiveness, and on the other hand the washerwoman with her quite deplorable inefficiency. The remaining solution—that of the housewife herself tackling the household washing—is a counsel of perfection, and exhaustion. Only with the aid of electricity does domestic washing become a process which can be carried through without a serious drain on energy, health, and time.

The typical washerwoman is a brawny female, with muscular arms and a tireless back. Washing by hand involves hard rubbing and vigorous wringing in an atmosphere of steam flavoured with soap-suds. "Black Monday" is the ancient title given to washing-day; and no title was ever more justly bestowed. Efforts have been made to mitigate its worst features by means of hand-operated machines, but the labour needed to work them is so little short of what is needed without them that they have never come into general use. The virtue of the electric washing machine lies in the fact that all the hard work is done by an electric motor.

It is impossible to give a description of all the varieties of electric washing machine. Some can be fitted on to the ordinary square washing tubs; others are self-contained appliances, generally with a wringer attached. Some employ the "vacuum" dolly frequently used in hand washing; others have special forms of dolly for thoroughly mixing the clothes and soap-suds; others depend for their efficacy on the rotation or the swinging of specially shaped tubs. All are alike, however, in the fact that once the tub is "charged," the electric motor can be left to get on with the work. Having switched on the little electric motor which drives the machine,

the housewife can proceed with other duties until the time comes to take the clothes out.

The same motor which operates the tub drives the wringer



ANOTHER FORM OF ELECTRIC WASHING MACHINE AND WRINGER

The motor operating the washer and wringer is started and stopped by the handle at the side of the machine.

as well, the change over from tub to wringer being made instantly by a simple piece of mechanism. Having both hands free for the business, the user gets the wringing done in a much shorter time and much more efficiently than if she had

to work the wringer. When she gets to the stage of ironing, she can turn to another electric machine. The ordinary domestic electric flat-iron is admirable for handkerchiefs, blouses and other light fabrics, but no kind of hand iron can make the treatment of tablecloths and other large heavy fabrics other than laborious. To deal with these fabrics the electric ironing machine, heated by electricity and driven by an electric motor, has been devised. The labour of using it is confined to placing the clothes in the machine and taking them out again. It does the work, in fact, of the calenders with which every power laundry is equipped.

Each part of this electric washing equipment has the merit of doing its work thoroughly, with a minimum of labour and of destruction to the fabrics. This equipment, in short, takes the place of an ideal washerwoman, and its wages are a fraction of those demanded by the least competent of women. The motors which drive the washing machine and the ironer are very small ; and as they are generally in use only for an hour or two one day in the week they add a negligible amount to the electricity bill. One American electricity supply company was indeed so much impressed with the meagre demand of the electric washing machine for electric current that it was inclined not to trouble about encouraging its consumers to buy the machine. To meet the case it hit upon the happy idea of giving to each buyer of an electric washer a coupon worth one dollar when used for purchasing any other electrical appliance at the showrooms. Thus people were encouraged to go to the showroom and buy an electric grill or fire or fan or some other piece of electrical apparatus which would be used every day and bring in a decent revenue to the company year after year. This characteristically Yankee dodge affords the best possible testimonial to the economy of the electric washer.

All these labour-saving devices depend, it will be noted, upon the electric motor. They do not, however, exhaust the services which the electric motor renders in the home. Wherever almost any form of " elbow-grease " is required, the little motor can be used to supply it.

Polishing—as applied to boots, plate, fire-irons, and metal

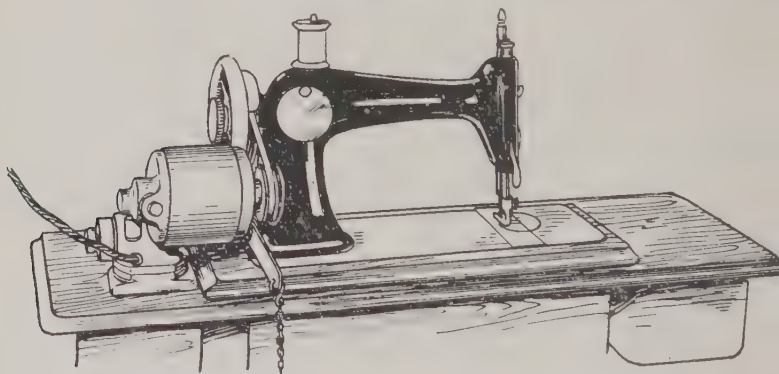
articles generally—is a most laborious operation when performed by hand. By using an electric motor it can be done in a fraction of the time and with practically no labour. The usual plan is to fix on a bench a small motor with a spindle to which various forms of brushes and polishers may be attached as required. In cleaning boots, for example, a hard brush is first employed to remove mud, then a softer one to apply the polish, and finally a polishing cloth. Generally the spindle carries an appliance at each end, so that for ordinary cleaning there is no need to waste even the second or two involved in changing the accessory.

Plate can be cleaned by placing on the spindle the “ buffers ” which are employed by silversmiths in obtaining that beautiful polish characteristic of plate fresh from the shop. Used with ordinary discretion the electric machine causes far less wear on silver or any other metal than the hand treatment to which it is usually subjected. The high speed at which the buffer runs enables it to clean with the lightest pressure of the softest material. Where the articles are heavy or of such a form that it is not convenient to hold them against the revolving buffer, a flexible shaft—similar to the one used in a dentist’s drill—can be fixed to the spindle at one end and fitted with the buffer at the other. In either of these ways a great variety of articles—stair-rods, fire-irons, fenders, coal-scuttles, and so on—can be swiftly polished with a very trifling consumption of electricity.

Where a lower speed is required, as in driving mincing machines, dough mixers, knife machines, potato peelers and other kitchen appliances, it is necessary to fit the electric motor with a belt or other speed-reducing gear. This is quite a simple matter, and complete outfits have been devised to enable one small motor to be applied, by means of simple attachments, to the driving of all sorts of machines generally worked by hand. In the small household, where the amount of food preparation is not formidable, the use of such equipment may be looked upon as rather a luxury, but it becomes more advantageous as the volume of work grows. In boarding-houses, hotels, and restaurants, where cooking becomes wholesale, it will some day be regarded as a necessity.

One small electric device for the kitchen deserves special mention on account of the remarkable amount of labour it saves. "Beat up the eggs" is a frequent formula in cooking recipes, and one which the cook greets with a sigh. She need sigh no more. The electric egg-whisk, which consists of a tiny electric motor with a vertical spindle carrying a small figure of eight piece on its lower end, will do the business beautifully in a minute or two.

The electrically driven sewing machine is an appliance which commends itself at once. By means of a controller operated by the foot the speed of driving is under perfect control. Both hands are free to adjust the work, and the



Sewing machines can be driven rapidly and under perfect control by means of a tiny electric motor.

motor drives the machine at a higher speed than is possible with either hand or foot operation.

Another labour-saver in the home, especially in the home of many stories, is the electric service lift. This can be fitted without much difficulty into most houses and is exceedingly useful in reducing the amount of work involved in conveying dishes and other things from floor to floor. The action of the lift can be made automatic, so that all the user needs to do is to press the button corresponding to the floor to which the lift has to be sent. If the lift is used largely in serving meals, it can be electrically heated so that the dishes do not become cold in transit from the kitchen to the dining-room.

These are the chief ways in which labour may be saved in the home by means of electricity. Their advantages should not, however, distract attention from ways, independent of electricity, by which the amount of work that falls to be done may be reduced. The use of stainless steel for knives, stair-rods, fenders, and so on removes the necessity of polishing even by electrical aid ; and the use of linoleum, the substitution of light curtains for heavy, the adoption of distemper instead of wall-paper, and similar changes will materially lighten the burden of housework. Only to a limited extent, however, can existing houses be relieved of this burden. In order to get as near as possible to the ideal we must look to new houses, which can be built and furnished with a single eye to cutting out unnecessary work.

We need not dwell in detail upon the parquet flooring, the marble-covered door-steps, the elimination of moulded skirting boards and cornices, and the other refinements by which the path of the duster and the cleaner may be made easy. These are among the devices, and occasionally the fads, of up-to-date domestic architecture. What is most interesting from our point of view is the way in which the entire design and construction of a house are simplified by using electricity freely.

Chimneys are one of the worries of the architect. They take up space and involve all sorts of compromises in fitting them into suitable positions. An all-electric home can be built without chimneys, thus giving larger rooms on the same ground or enabling equal accommodation to be given on a smaller and therefore cheaper scale. We may note also that the use of electric light enables somewhat lower ceilings to be adopted without any detriment to health or comfort ; this again reduces the cost of the house. As regards ventilation, a chimney flue in a room is regarded as essential, but we must remember that the current of air it induces takes the objectional form of a cold stream along the floor. By means of ventilating bricks and small flues opening into the upper part of the wall a much more healthy circulation of air can be obtained at a much lower cost.

Again, the cheapness of electric light leads to economy in

the matter of windows. The housewife demands good light over the cooking range, the scullery sink, and other places where much work has to be done ; and the architect meets the demand by multiplying the number of windows, especially where the proximity of other buildings reduces the amount of daylight available. It is such a simple matter, however, to fix a small lamp over the place where extra light is wanted, and it is so cheap to use such a lamp that the needs of the case are most economically met by limiting the number of the windows to what is necessary for general lighting and using electric light as an auxiliary when extra local lighting is wanted.

Bearing in mind these simplifications, and that the elimination of chimneys wipes out the cost of the coal range, fireplaces, grates, fenders, and all the other accessories, it becomes easy to understand that an all-electric home can be built *and equipped with a considerable amount of electrical apparatus* at a lower cost than that of erecting an ordinary house with the same accommodation.

This is a very important claim, the importance of which is not yet fully realised. Even where the full all-electric principle is not adopted, a material saving in first cost can be realised. The affection which the British citizen has for a coal fire leads to the retention of at least one chimney even in houses designed for electric lighting, heating, and cooking. Moreover, if the combined central hot water and electric system described in Chapter IX is followed, a flue is required for the furnace. This exception does not, however, invalidate the rule. In the Tees-side district there have been erected a number of electric homes for workmen ; these houses have electric light, electric fires, an electric cooking range, and an electric copper. They have in addition one chimney breast with two fireplaces opening into it, one in a bedroom and the other in the kitchen with a boiler. The total cost of building and equipping electrically these houses was less than the estimate of ordinary houses of the same type by thirty pounds per house.

We must, therefore, add economy in building construction to the many other economies which the use of electricity in the home enables us to enjoy.

CHAPTER XII

ELECTRICITY AND HEALTH

HERE and there in the previous chapters an occasional reference has been made to the benefits which electricity confers on health. A town where electricity is freely used for the driving of factories and for heating and cooking will have a clearer and purer atmosphere than one in which raw coal is burned in small furnaces or open grates. Factories which are " electrified " have more air than those filled with belting and shafting ; they can be illuminated on ideal lines. In the home electricity means purer air, brighter rooms, less dust, and less exhausting labour. Electric cooking is more hygienic than other methods and more likely to give digestible dishes. Electric heat is pure heat, and the electric cleaner is the most efficient remover of dust, which is the harbinger of germs.

Beyond these familiar items, however, there is a long list of specific services which electricity renders in preserving health or curing disease. Only a few of the more typical ones can be mentioned here.

One of the first applications of the electric motor was, as we saw in an early chapter, to the driving of a ventilating fan on board ship. The ease with which a motor and air propeller could be mounted together and fixed in any position led to a wide extension of electric ventilation not only on board ship, but in mines, factories, and large buildings. By installing electric fans in connection with a system of ducts it was possible to fulfil the ventilating experts' demand that the air in a building should be changed so many times per hour. The accepted theory was that if a certain amount of fresh air at the proper temperature were supplied to the interior, the ventilation would be satisfactory.

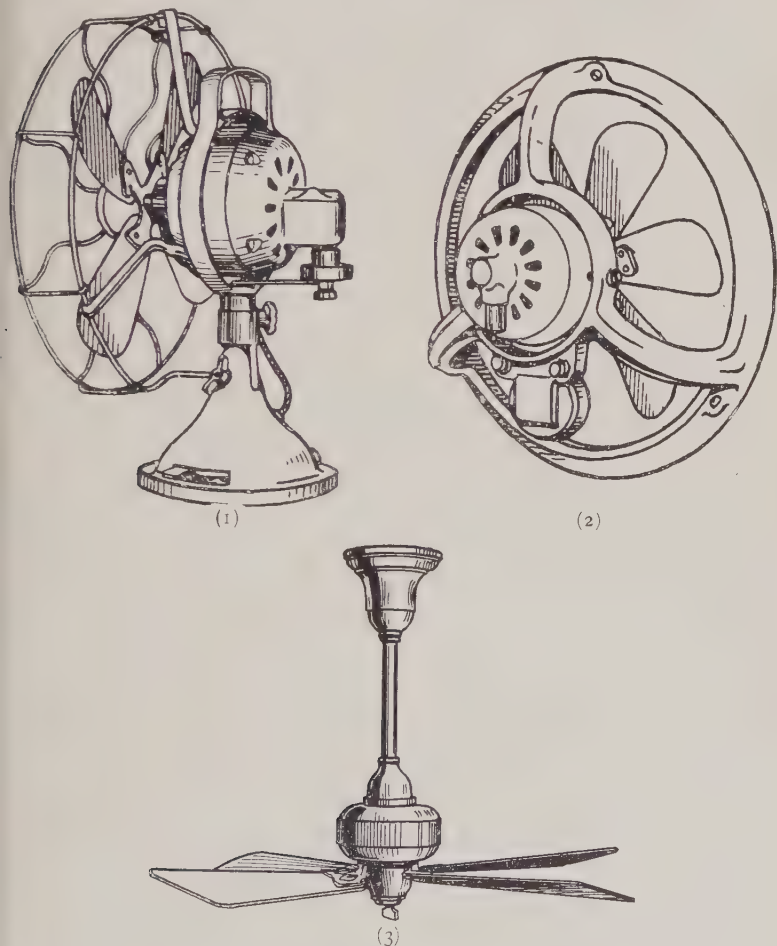
Experience showed, however, that something more was needed. "Scientifically" ventilated buildings proved to be stuffy and oppressive in spite of the certified freshness of the air. The researches made by Dr. Leonard Hill brought out the fact that the desired feeling of freshness was due more to the state of motion of the air than to its chemical composition. Thus a room with plenty of carbonic acid gas and tobacco smoke would feel healthier, if the air were in movement, than a still atmosphere with no impurities.

The reason lies in the evaporative action of moving air upon the skin. Everyone must have noticed that a still summer day is much more oppressive than one when a light breeze is blowing, even though the temperature may be much higher in the latter case. The man who, many centuries ago, invented the ordinary fan, had a better grasp of the essentials of ventilation than some modern engineers. And the electric fan, either in the form of the little portable table or bracket fan, the large ceiling fan, or the electric punkah, is the direct descendant of the primitive fan. Its function is the same—to stir the air and increase evaporation from the skin. With our climate we need this aid, in our homes at any rate, only on sultry summer days, but there are many cases, in restaurants, smoke rooms, and public buildings, where the agitation produced by an electric fan is a great advantage.

The most convenient form of electric fan for ordinary domestic use is the oscillating desk fan, which swings automatically from side to side and so stirs the air over a wide range. An appliance of this kind should be regarded not as a luxury, but as almost a necessity to health in the dog days. It removes the feeling of exhaustion, verging sometimes on collapse, from which many people suffer during hot weather. It is useful in the nursery and bedroom for inducing sound, healthy sleep on hot nights; and in the sick room it is invaluable. Ignorance of the relief afforded by the electric fan, which takes no more current than an ordinary lamp, has led to countless patients suffering from sleeplessness and weakness, due to exposure to heat in a still atmosphere.

In addition to the improvement it effects on the atmosphere of towns and of buildings, electricity has one or two direct

relations with the public health. Perhaps the most effective way of sterilising water is by exposing it to the action of the



THREE TYPES OF ELECTRIC FANS

(1) The small desk or bracket fan, which swings from side to side. (2) The "port-hole" type, which exhausts foul air from rooms or workshops. (3) The "punkah" or ceiling fan, which stirs the air over a wide space.

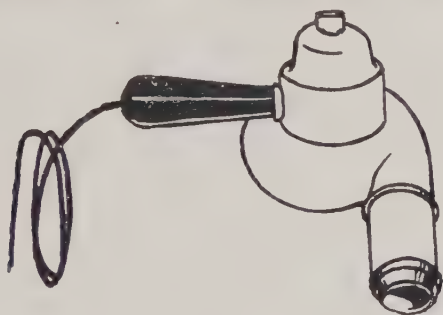
"ultra-violet" rays from certain types of arc lamp. The dangerous germs in milk can also be destroyed by electrical action; a depot for the supply of electrically sterilised milk

has been in operation in Liverpool for some time. In Poplar the Medical Officer of Health organised many years ago a public supply of electrolytic disinfecting fluid, made by passing a current of electricity through a solution of certain salts. Large quantities of this fluid are supplied to the public baths and institutions; and the general public can have as much as desired at the sole cost of bringing a vessel to be filled. With the increase of public interest in health questions, these preventive measures are likely to be more widely adopted.

When we turn from the prevention of illness to the cure of disease we enter a field which extends on the one hand to fraud and quackery, and on the other to some of the most remarkable triumphs of medicine and surgery. So vast and so crowded is this field, and so rapidly is it being developed by many different kinds of specialist, that no comprehensive book on the subject has yet been written; and, were it attempted, most of its information would be out of date before it was published. A description of some of the more familiar and impressive applications of electricity in medical and surgical work will, however, explain why so many doctors are tilling this field with increasing enthusiasm.

The action of a nerve in transmitting the impulse which contracts a muscle or induces a gland to secrete is not only analogous to the passage of an electric current along a telegraph wire but is really an electrical phenomenon. Therefore the machinery of the body may be affected by passing currents of electricity through it, or inducing currents in it, or by charging it with electricity. The general effect is to stimulate the activity of the nerves and thus restore vitality to weakened organs, but different kinds of current have different results, and no form of electro-medical treatment should be attempted except under expert medical advice. The only exception to this rule is in the case of "electric belts" and "anti-rheumatic" rings, which are supposed, by the contact of metals upon moist skin, to set up curative currents in the tissues. These currents, however, are so minute that they could not hurt anybody; and the benefits they confer are in proportion to the faith of the user.

Electro-medical treatment has a language of its own. It speaks of "galvanic" current, when it means "direct" current, which flows continuously in the same direction. It speaks of "faradic" current, when it means "alternating" current, which changes its direction many times per second. Galvanic current for medical purposes is generally produced by a battery, and faradic current by an induction coil. Both are of great value in diagnosis, as nerves react to faradic currents and muscles to galvanic currents, so that by the nature of the reaction a doctor can discover the condition of the nerve or muscle. In the treatment of disease each may be used by



An electric fan and electric heater are combined in this appliance to give a hot current of air for medical purposes or for hair drying.

itself or along with the other for an almost bewildering variety of purposes.

One of the outstanding modes of treatment is by the "electric bath." The patient is placed in a deep bath of warm water, and one electric terminal or "electrode" is brought to his back and the other to his feet. Currents of any desired strength and character can be sent through his body, either to produce a tonic effect in cases of neurasthenia or general weakness, or to relieve the pain of neuritis, lumbago, rheumatism, and so on. A more convenient way of applying this treatment is by the "four-cell" bath, consisting simply of four receptacles into which the patient, dressed and comfortably seated, places his hands and feet. With this arrangement the current can be sent in any direction through the patient's

body, and much larger currents can be applied without discomfort.

Local electrical treatment can be given without the electric bath, by placing one electrode on a patient's back and using another (either a wire brush or roller) applied to the skin in the region of the affected part. Paralysis and various nervous disorders, sciatica, lumbago, headache, neuritis, dilation of the stomach, and other troubles may be relieved by skilful application of either faradic or galvanic current on this system.

Two other forms of electrical treatment must be mentioned—"static" and "high frequency." In the first the patient is seated on an insulated stool with his feet resting on a metal plate connected to an electrical machine which "charges" him with electricity. The electricity is either allowed to ooze slowly from him, or it is removed to the accompaniment of sparks by passing a roller (connected to the machine) over his skin, or is extracted in a "breeze" by bringing an electrode with several points near the skin. The chief purposes of this treatment is to relieve headache and neuralgia.

High-frequency treatment depends upon a curious electro-medical fact. Faradic current, as we have mentioned, changes its direction many times per second; and if the rapidity of the change is increased, the stimulating effect on the tissues becomes less. When the frequency of change is 50,000 per second, no such effect can be detected. Treatment by such high-frequency currents is credited with a general tonic influence, and many people use it more or less freely with that end in view. The apparatus required for producing high-frequency currents is very compact and so harmless in use that it is sold direct to the public. It is alleged that Members of Parliament and other orators often employ this treatment before making important speeches, but the general level of public speaking rather suggests that the stimulating effect of high-frequency currents on mental activity has narrow limitations.

More interesting still is the use of high-frequency currents to warm the deep-seated portions of the body. Without the aid of electricity it is very difficult to convey heat to any tissue

which are not close to the skin. The skin itself is a bad conductor of heat, so that it retards the downward passage of heat from any hot body placed upon it. When, however, a high-frequency current with 100,000 changes of direction per second is passed through the tissues, the strength of the current can be increased until it sensibly warms the tissues *right through*. There is no tingling, no muscular contraction—merely a feeling of warmth. Any part can be warmed by placing an electrode on each side of the part. By making one of the electrodes very small the local heating becomes so great that the blood may be coagulated and the tissue destroyed. Therefore “diathermy,” as this method is called, can be used to kill malignant growths *in situ*. A most striking application of diathermy is in the cure of a very painful disease of the knee caused by a particular germ which thrives at the temperature of the body, but is killed if the temperature is raised by a few degrees. Heating the knee joint by high-frequency currents destroys the germ without harming the tissues.

Returning to galvanic or direct current, there are two other important fields of application, one of which depends upon the power of an electric current to decompose the fluids through which it passes. When current of a certain strength is passed through the tissues of the body, acids appear at one electrode and alkalis at the other. By this means a destructive influence can be localised to remove small surface tumours or blemishes or superfluous hairs; but in most cases the treatment, if carried out without anæsthetics, is painful. The second field of application—dignified by the name of “iontophoresis”—is much more interesting. Just as diathermy enables heat to be conveyed to deep-seated tissues, so iontophoresis conveys drugs to depths which could not otherwise be reached. The electric current acts as a carrier of the drug—not in the mass, but ion by ion, the ions being the ultimate corpuscles out of which the atoms are built. By this process a patch of skin can be rendered insensitive by cocaine in five minutes, thus enabling such operations as the removal of hairs, small tumours, and moles—electrically or otherwise—to be performed painlessly. Zinc for the treatment of rodent ulcer, copper for ringworm, lithium for gout or rheumatoid arthritis, magnesium

for warts, and salicylic acid for sciatica, neuralgia, and rheumatism, are other examples of treatment by iontophoresis.

A large number of electro-medical applications are concerned with *rays* of one sort or another. Radiant heat baths were mentioned in a previous chapter as a convenient means of inducing perspiration and thus cleansing the system; they have been used for many years in the treatment of gout, rheumatism, neuritis, and various other troubles. The ease with which the heat may be regulated enables the radiant electric bath treatment to be carefully adjusted to the requirements of each patient. It is not, however, heat alone which accounts for the relief which many people secure from electric light baths. The special lamps employed give a light which is rich in "ultra-violet rays"—those rays which lie invisible beyond the blue in the rainbow spectrum of sunlight. These rays are credited with healing properties and with being the secret of the efficacy of "sun-baths" at high altitudes, where the sunlight reaches us without having to pass through denser atmosphere which absorbs the ultra-violet rays. Thus the electric light bath is an efficient and convenient substitute for the sun-bath. Instead of the patient having to go to the mountain, the healing virtues of the sunny hill-top are brought into his home.

Electric fires have also been made to give a sun-ray effect. They produce a bright glow with a soft, penetrating warmth which is pleasant and invigorating, especially on a dull winter's day. Electricity may thus give us an antidote to the depressing effect of our clouds and fogs.

Many years ago Professor Finsen discovered that ultra-violet rays tended to kill bacteria, and he followed up his discovery by treating lupus with sunlight. The drawback to sunlight is that it is not always available, and accordingly the Finsen treatment is now given by a special electric arc lamp which affords a light rich in ultra-violet rays. Septic wounds, chronic ulcers, eczema, and baldness due to micro-organisms in the scalp have also been successfully treated, and the rays have been used in the detection and cure of pyorrhea.

X-rays form a big subject by themselves, and one of extraordinary fascination. They are a kind of light produced by

the discharge of electricity through a vacuum tube, and they are able to penetrate all substances to a greater or less extent. The denser the substance the less the penetration, so that a photograph taken by X-rays of the hand, or of a purse with coins in it, is a kind of shadow-picture in which the denser materials are represented by dark patches.

There is no need to tell in detail how X-rays rapidly passed from a scientific curiosity to a valuable means of locating foreign bodies, examining broken bones, and studying the shape and operation of internal organs. Nor need we say much about the direct use of the rays in the cure of ringworm and other skin diseases. The future possibilities of X-rays are of greater interest than these familiar achievements ; and it is through the discovered dangers of X-rays that these possibilities hold out the greatest hopes. The first X-ray tubes, which gave " soft " rays of low penetrating power, caused inflammation of the skin after prolonged exposure ; but this danger, which claimed more than one heroic and uncomplaining victim, was met by the use of protective screens of lead—the densest material which could be conveniently employed. When " hard " tubes of great penetrating power were produced, they were thought to be free from any new risk, but it has been discovered that they have—if the exposure is practically continuous over a long period—a fatal effect on the cells of the bone marrow and also upon the reproductive cells. An organised attempt is being made to discover some way of guarding against this danger ; and this quest holds within it the kernel of a greater hope. The cells of cancerous tissue are in a sense reproductive cells ; they seem to have a life of their own. Therefore, if we can find some kind of X-ray, or some way of applying X-rays, so that cancer cells are killed while healthy tissue is not harmed, we shall be led to a cure for one of the most devastating scourges. Some advance along this path has already been made.

Apart from these special forms of treatment, electricity plays a very large part in hospital work. It provides the best means of lighting the operating theatre, as the lamps can be placed in any position and fitted with reflectors which give precisely the kind of illumination which the surgeon requires

for any kind of work. Moreover, a duplicate supply of current can be arranged from a secondary battery which is kept charged and comes into operation automatically, and without even an intervening blink, the instant the main current fails through any cause.

Minute electric lamps, fitted in special devices with lenses and reflectors, are used for the examination of the throat, ear, stomach and other internal organs. Magnets are invaluable for extracting pieces of metal from the eye. The electric cautery, which consists of a small "cutter" of platinum heated to white heat by an electric current, is invaluable for many purposes, as it does its work so rapidly and cleanly that only the tissues touched are burned. Electric sterilisers are also largely used on account of their convenience and absolute cleanliness. Radiant electric heat is coming into use for keeping up the body temperature of patients suffering from shock. It is much safer and more effective than hot-water bottles. For local heating electric pads are very convenient, and compresses are made in different shapes for treating different parts of the body. These compresses are fitted with automatic regulators so that the temperature can be accurately adjusted. Hot and cold air douches can be given by an appliance which consists of a small electric fan propelling air over an electric heating element, which may be switched on or off as required. This instrument is also useful for drying hair and heating beds.

High-frequency treatment is often given in conjunction with ordinary massage, but electricity plays a more direct part in the mechanical stimulation which the masseur produces. The electric vibrator is one of the most perfect instruments of its kind, giving a rapid vibratory movement (20,000 per minute) to the rubber "applicators" by means of a tiny electric motor. It has come into frequent use for stimulating the growth of the hair, promoting the healthy action of the skin, relieving pain, and generally toning up the system.

One of the most interesting examples of the aid which electricity renders to health was supplied by the Pilkington Hospital established at St. Helens during the War for the treatment of soldiers suffering from damaged limbs. The object of the treatment was to restore the working of the limb after the

severed nerves and damaged tissues had been patched up by the surgeon. Heat was applied to the various parts by special electrical means, and whirlpool baths, in which water was kept in constant agitation by electric pumps, were found most valuable in stimulating muscles and nerves back to normal activity.

Incomplete as our survey of the field of electrical service has been, it shows that the popular faith in "electrical treatment" is well founded. And it also, we hope, suggests that we are on the eve of still more remarkable discoveries for the preservation of health and the cure of disease.

CHAPTER XIII

ELECTRICITY IN COMMUNICATION

IF electricity had never been applied to anything but the sending of messages from one part of the earth to another, it would still deserve to rank as one of the greatest blessings conferred by science upon the human race. In the field of communication it stands alone. Electricity is the sole means by which a signal can be instantly conveyed over tens, hundreds, or thousands of miles. It began to be applied about a hundred years ago to this purpose first on a modest scale over a few hundreds of yards, then slowly extending its range and increasing its speed until it became the medium by which nation kept in touch with nation, and continent with continent.

Books on history say little about the influence upon the growth and consolidation of the British Empire, upon the effective unity of the United States, and upon the development of world commerce with all its educative and civilising effects, of the advance of telegraphy in the nineteenth century. Kings and statesmen, war and politics, figure more largely in their pages than the steamship, the steam engine, the telegraph, and all the other inventions which in the course of two or three generations changed the face of the globe. To a large extent the political idealism of the present day finds its most secure foundation in the achievements of science and engineering which cut through ancient barriers, break down the isolation of communities, and bring peoples of alien thought and tradition into close daily contact with each other.

This is a theme which deserves to be expounded on a much broader scale than is here possible. All we can attempt in this chapter is a brief review of the history of electrical communication, with special reference to some of the latest and most fascinating developments.

Telegraphy and telephony differ from most of the applications of electricity we have described in using weak currents. Thus the telegraph was in a highly developed state long before the dynamo had been invented ; and the telephone had been found practicable—in 1876—before commercial electric lighting and electric traction were born. The first telegraph instruments were used on railways, where their advantages were manifest ; and it was only by degrees that the public came to appreciate the value, for business and social purposes, of so rapid a means of communication. At first it was possible to send only one message along each wire, but in 1853 a method of sending two messages at the same time in opposite directions along a wire was invented. In 1877 another stage was reached, when two messages in each direction were sent simultaneously. As the speed of telegraphic signalling by hand is limited to about forty words per minute, progress in high-speed telegraphy has lain with devices which enable several operators to use the same line at the same time. One equipment used by the Post Office enables from 160 to 200 messages to be sent each way in an hour, the messages being printed direct in page form at the receiving end. Most of the telegraphic business between London and Manchester can be handled by a single apparatus of this kind : indeed there are few cases where the traffic is heavy enough to keep it occupied.

In submarine telegraphy, unfortunately, it is not possible, for electrical reasons, to put so much traffic through a single cable. The first Atlantic cable was laid by Sir Charles Bright in 1858, and by 1871 the highest speed attained was 15 words, or about 75 letters, per minute. To-day this limit has been raised to 150 letters per minute in both directions simultaneously. Electrical engineers do not despair of getting still better results, but they are more inclined to look to wireless telegraphy and wireless telephony for providing the additional channels of communication required across the seas.

The telephone is so familiar an element in daily life that little need be said about its function and its value. The Government treated it first as a toy, and then as an unwelcome rival to the telegraph, on which account the pioneers of public telephone services were hampered and harassed in every way

that a Government could contrive. For ten years the telephone system has been in State hands ; and the day has not yet come when the telephone is a recognised feature in the average home—as it ought to be. The most important development of recent years has been the Automatic Exchange, in which the human operator, who is the object of complaint, is replaced by mechanism which never makes mistakes. Automatic exchanges on a small scale have been very successfully applied to factories, docks, hospitals, and other large institutions, where they provide a most reliable and convenient means of secret intercommunication.

Before touching on wireless communication, a word must be said upon an unsolved problem of electrical communication by wire. Telegraphy is a means of reproducing movement at a distance ; by its aid one can actually duplicate one's handwriting a hundred miles away. Telephony is a means of reproducing sound ; the transmitter into which we speak changes the sound waves into electric currents, which are converted back to sound waves by the receiver. Is it possible to transmit light vibrations electrically in such a way that we can " see " at a distance ?

A short step towards the solution of this problem of " seeing by electricity " has been made in the transmission of photographs or sketches. By using a selenium cell, which alters its electrical resistance with the intensity of the light falling upon it, electric currents can be made to vary according to light and shade. Copies of photographs have been transmitted seven hundred miles by this means ; and some success has been attained also by wireless transmission. The apparatus, however, spells out the picture, as it were, dot by dot : and something more is needed before the entire picture can be made visible at once. Mr. Llewelyn Atkinson (President of the Institution of Electrical Engineers, 1920-21) is convinced that all the elements of a solution are at hand. He considers that wireless transmission is essential, so that, following upon the recent achievement of wireless telephony, we have the prospect of actually seeing the people to whom we talk across space.

The selenium cell, it may be mentioned, has been applied to operate light buoys and street lamps, providing an auto-

matic means of switching them on at dusk and off at dawn. It has also been used in the optophone, a marvellous electrical instrument which enables the blind to "read" ordinary type by sound.

It is the fashion to treat wireless communication as much more mysterious than ordinary telegraphy or telephony by wire, but from the scientific standpoint it is not a whit more mysterious. The underlying principle is quite familiar. It operates when the light waves set up by a lamp meet the eye and give us the sensation of light, or when the light waves from the sun cause the daisy to open. To use another analogy, a wireless transmitter sets up electric waves in the ether as a dropped stone sets up waves in a pond; and the wireless receiver responds to them as a cork would to the ripples set up by the stone. The peculiar marvel about wireless telegraphy is that we have been able to devise a detector sensitive enough to respond to electric waves set up thousands of miles away. In 1896, when Marconi had produced the first workable wireless apparatus, transmission was carried on over only a few miles. Improvement, however, was rapid: and in 1901 wireless signals were sent across the Atlantic. Recently direct communication was established between Great Britain and Australia, a distance of twelve thousand miles.

Such later achievements in wireless telegraphy, and all the astonishing triumphs of wireless telephony, depend upon a device which evolved from the electric incandescent lamp. Edison discovered that the lamp allowed current to pass between the filament and a piece of metal inside the bulb; and in 1913 Professor Fleming, of University College, London, found that the apparatus was a very sensitive detector of electric waves. Its effect was to magnify the waves, so that faint ripples which would not disturb the ordinary detector were greatly amplified. Thus was born the apparatus which, in a developed form, is known as the "thermionic valve," and is being used not only in wireless work but in long-distance telephony by wire and for many other purposes. It is one of the greatest of electrical wonders, but its qualities were obscured by the circumstance that it was put into service during the War, when little could be said in public about it.

As Mr. Llewelyn Atkinson said in his Presidential Address to the Institution of Electrical Engineers in 1920, "I often think if only it had been introduced complete to one of our meetings, like the telephone, the microphone, or some of the earlier electric discoveries, what a furore would have been created."

The wireless telephone is now taking the place of the wireless telegraph in several directions. It is part of the regular equipment of aeroplanes, being used for communication between planes and from the plane to land stations. Under the somewhat similar conditions of communication between ships and the shore, notably in the case of lightships, it is also useful. The range of action has already reached the astonishing distance of close on five thousand miles, though regular commercial service has not yet been developed on that scale.

Many interesting experiments have been carried out in the transmission of music. The electrophone has made us familiar with the possibility of extending the audience at a concert by means of telephone wires. With wireless telephony an unlimited number of auditors may share in the performance. Various projects have been suggested for distributing news by wireless telephony over wide areas, but there are great difficulties about putting these visions into concrete commercial form. They are mentioned merely to show that in the matter of wireless communication we are only at the beginning of things.

In two directions wireless communication has already become domesticated. At quite a moderate cost one can set up a small set capable of receiving signals from neighbouring stations of moderate power and from the big stations at a distance. Many "wireless amateurs" find this a most fascinating hobby. Among the signals which can readily be detected are the time-signals sent out regularly from the wireless station at the Eiffel Tower. They afford an accurate means of setting clocks and are therefore useful to the householder as well as to the navigator. Small wireless receivers, designed specially for the reception of time signals, are made for the use of watch-makers, and they can be used to check or control "master

clocks " in the installations of electric clocks which are provided in every up-to-date public building. In these installations the dials in the various rooms are electrically controlled from the master clock, so that they keep step exactly ; and with wireless control of the master clock the distribution of correct time becomes automatic. There is no reason, except public apathy, why this system should not be applied to all the clocks in a city. The manner in which unregulated clocks on churches and other buildings are allowed to give the lie to each other was always a scandal and is now an easily avoidable one.

CHAPTER XIV

THE FUTURE

AMONG the various Utopias which men have conjured up to console themselves for the imperfections of life the least satisfying are the mechanical Utopias, in which the building of houses, locomotion, the preparation of food, and all the other external affairs of daily existence proceed without human effort. It must be confessed that electricity plays a large part in these visions. Work is reduced to the pressing of buttons, which summon up aid as versatile and efficient as the genii of the Arabian Nights. Life becomes vegetative in the midst of shining, silent, smoothly running machinery behind the scenes.

The all-electric age which forms the goal, or if one pleases the Utopia, of the electrical engineer is quite a different affair. It contains nothing extravagant, nothing that demands a new kind of human being in order to be enjoyable or even tolerable. We gain our picture of it not by a kind of Futurist sketch which looks like nothing on earth, but simply by extending certain lines of progress already laid down. The parts drawn in the preceding chapters are, it must be emphasised, glimpses of the actual in nearly all cases. By taking the most advanced examples of electrical applications in each direction—domestic, industrial, and so on—and by imagining these examples becoming common instead of more or less exceptional, we complete the prospectus of the all-electric age. Nothing, in short, is assumed except an abundant supply of cheap electricity, and the readiness of people to use it to the full for their own advantage.

Perhaps the best way of realising what things would be like when the use of electricity has approached the universal stage

is to imagine a journey taken from some remote spot in the country through villages and town to a city. The line of travel is from the primitive to the sophisticated, but we shall find electricity at work all the way.



HOW ELECTRICITY IS CONVEYED CHEAPLY TO REMOTE
COUNTRY DISTRICTS

These overhead wires carry enough power to light
and operate a farm

We find it, to begin with, transforming the life of the farmer. Hitherto the farmer has relied mainly upon men and horses, supplemented in some cases by small engines for special purposes. Now he finds himself able to operate his farm as if

it were a factory. Electric current reaches him by overhead mains radiating—as at Hereford—for ten or fifteen miles beyond a town or—as in Yorkshire and elsewhere—traversing miles of open country from a big power station to a distant colliery and other isolated industry. He uses it first for lighting the homestead and farm buildings and sheep-folds, thus making his home more cheerful, reducing the risk of fire, increasing his security, and facilitating work on dark winter mornings and after dusk. His wife uses it for cooking and heating, for ironing, and for other domestic purposes, thus lightening her labour and reducing the amount of fuel which has to be transported, always at considerable expense, to the farm. In the dairy it is used for operating churns and cream separators, driving the refrigerator, and milking the cows. Electric milking has been found more satisfactory than hand milking, because the cows have no prejudice against it as they have against certain human milkers, and because it is absolutely hygienic. Where, as is usually the case, water has to be raised into a cistern for farm use, an electric pump, which starts automatically when the level of the water falls, takes the place of laborious and time-wasting pumping by hand. In a similar way, water can be conveyed to distant parts of the land for irrigation and other purposes. The spraying of orchard and hop plants can be conveniently done by a small electric pump mounted on runners or wheels for easy transfer from point to point. Chaff-cutting, turnip slicing, and such operations are done by electric power in a fraction of the time required by manual labour. By using a portable motor connected to the source of supply by a flexible cable sheathed in hard rubber, one machine can be used to drive several appliances at different times—such as threshers, hoists, and stacking machines.

In actual cultivation electricity finds two modes of application. One is in connection with ploughing. A widely used form of electric plough requires two motors, on opposite sides of the field, operating drums which haul the plough backwards and forwards on a wire rope. The equipment is made portable, so that it may be transferred from one field to another. The second application lies in the stimulation

of crops. This is a matter on which there is still a certain amount of doubt. Many experiments have been made which indicate that discharges of high-tension electricity from wires strung over a field do produce heavier and healthier crops, but the problem is so complicated with elements of seed, soil, and weather that one cannot say positively that all or any of the improvement is due to electricity. It is still uncertain, also, in what way electrical discharges can or do affect plant life. The most likely thing is that they kill off noxious bacteria in the soil and so favour the growth of crops. For some time past a sub-committee of the Ministry of Agriculture has been studying the question, and at some early date we may find that the electrical treatment of plant diseases ranks with electro-medicine as a healthy branch of science.

The general effect of electricity in agriculture is to cut out most of the hard, monotonous labour. Farmers should welcome the change, because they no longer have a plentiful supply of cheap labour, and there is a growing tendency to reduce the hours of farm work to something like factory hours. Under such conditions the only way to maintain the output of farm produce is to use power. And electric power is far and away the handiest form, raising the standard of efficiency all round, and vastly improving the amenities of labour and life on the farm.

In the country house there is also a labour problem. Domestic help is extremely difficult to obtain, partly owing to the quietness of the life and partly to the exceptional amount of work which falls to be done in a home lit by oil lamps, wholly dependent upon coal for heating and cooking, and primitive in many of its arrangements. A supply of electricity brings with it all the conveniences of an up-to-date town house and robs the simple life of all its embarrassments. From certain points of view the advantages of the all-electric system are greater in the open country than in a town. The cost of fuel is swollen by the expense of cartage, and there is an even greater necessity for reducing hand labour to the minimum. Hitherto, only the larger country houses have enjoyed a supply of electricity, the usual plan being to install a little oil-driven generating plant to produce current for lighting purposes.

When overhead mains are extended into the country, small as well as large houses can find ample power not only for lighting but for all domestic purposes.

Another result of electrification in the country is that the isolation which is, to some people, at any rate, the great drawback of rural life, is mitigated. The telephone is an invaluable link with neighbours, doctors, and markets ; and there is no reason why the simple and convenient small electric car should not become a common possession. As already pointed out, it is the most economical car to run and to maintain, and it can readily be driven by anyone. Apart, therefore, from the development of public road transport, electricity serves to bring the scattered houses closer to each other and to railway stations and shopping centres.

In the case of country villages and small towns, the general effect of electricity supply is a quickening of the pulse of life and a brightening of the environment. Electric light is now so cheap that without any strain on slender finances the streets, public buildings, shops and houses of Sweet Auburn may become as cheerful as the central thoroughfares of a city. Bad lighting is at the root of a good deal of the dullness and depression of life in a small town. Cheap electricity, we may also mention, encourages the establishment of "electric theatres" which are so potent a magnet for people who must have some fresh dramatic attraction every week. But apart from these things, no village or small town can hold the younger generation unless it provides a good market for labour. In the old days of handicraft every small town had its quota of well-to-do craftsmen, but with the development of steam power these local centres of production died away and skilled labour drifted to the large factory towns. The provision of electric power should lead to a revival of industrial life in small towns enabling local men to compete successfully in carpentry, cabinet making, small engineering repairs, garage work, and similar industries with larger firms in distant towns. It is the ambition of many social reformers to re-establish village industries ; this process will become feasible when it finds its driving force in electric power.

We may note, in passing, that the electrification of a small

town or village destroys none of the amenities which so often suffer in the march of "improvement." Overhead electric wires are practically indistinguishable from telegraph wires, to which everybody has now become accustomed; and if skilfully placed they will be hardly noticed at all. Electricity for power, heating, and cooking reduces the volume of smoke, abolishes the noise and nuisance attached to the use of engines, and lightens everyone's labour. Just as the country house can be made as comfortable as the town house by the full use of electricity, so the country town can enjoy many of the advantages of the city without losing its quietness and its beauty.

Electricity is thus a powerful agent in the "back to the land" movement. And it can not only bring new prosperity to agriculture, and new life to the rural town, but it can effect a redistribution of industries on the large scale from congested cities to open country sites. Many factors have to be taken into account when selecting a factory site, the main ones being cheap land, low rates, cheap power, good transport facilities, and adequate labour supply. During the steam age factories crowded into towns adjacent to coal-mines because it was only there that cheap power and ready access to markets for the supply of raw materials and the disposal of products could be obtained. These advantages made up for the high cost of land and the burden of city rates.

On the other hand, given electric power, which can be cheaply transmitted for ten or twenty miles, a much wider range of selection is opened up. It then becomes commercially possible to build factories on open healthy sites and amid pleasant surroundings. If the site is reasonably close to a railway, transport presents little difficulty. Moreover, rail transport can always be supplemented by road transport. By placing the factory on the outskirts of a small town, a certain reservoir of labour can be tapped, but in many cases the scheme includes the building of a village or even of a small town to house the workers and to provide the shops and other elements of a self-contained community.

In this way the spread of electric power reverses the process of industrial centralisation which went on in the steam age and led to so many unfortunate results. For this reversal to

work its fullest benefit it is clearly essential that every encouragement should be given to the extension of overhead electric mains. Only by this means can cheap electric power become available in outlying districts where electric factories surrounded by clean garden villages can be established. Almost equally important is it that freedom of enterprise should be granted for the development of electrical forms of transport. The spread of electric power and the growth of electric transport should go hand in hand. A steam railway confers only a very limited benefit on the open country through which it passes, because its chief purpose is to provide direct communication between populous centres. But when that railway becomes electrified not only is the communication improved but the electric mains constructed for transport purposes become a "river of power" from which a wide tract of country on both sides of the line can be irrigated. In addition, the availability of cheap power encourages the building of light railways by which agricultural produce can be brought quickly on to main lines and passenger communication between villages augmented. As an alternative, electric trolley lines can be run along country roads.

The general result of all this electrical development in open territory is not only to stimulate village industries, to create new industrial centres, and to enable farmers to get their produce to market rapidly and cheaply, but to break down the isolation from which each little centre of population suffers at the present time. Nothing is more striking in our social arrangements than the contrast between the empty sluggish country and the congested over-active town. When the network of electric mains spreads from power stations, and branches from the routes of main line, local, and light railways, the population will tend to spread with it, and each little community, with its industries stimulated, will be in close contact with its neighbours, feeling the mental as well as the social and commercial benefits of easy communication. Time and space are the great dividers; electric power conquers both.

It is the fashion, we know, to represent life in the country and in isolated garden villages as idyllic. But the people who

sing fervently of the joys of primitive simplicity and isolation are usually those who turn to them only for occasional relief. For the majority of ordinary folk existence in the backwaters is narrow and deadening. When they have something which will lighten their daily labours, open up new industrial possibilities, and enable them to mingle freely with their fellow-men, they will enjoy much of the vital inspiration of town conditions without losing any of the real charm of closeness to Nature.

From that standpoint the services which electricity will render in the country, in villages, and in small towns are even more conspicuous than in the cities which are alleged to be so deeply in need of reform. Nevertheless, in our vision of the electrical future, the city will be a very different place from what it is to-day.

The most notable change will be in the atmosphere. When all our factories are driven by electric power from large, central stations, and when all our houses are equipped for the electric service which we have described, pollution of the atmosphere with smoke will be unknown. But long before that period, let us hope, the civic sense of the people will be sufficiently awakened to enforce a law that the burning of soft raw coal within city boundaries shall be prohibited. To-day we look back, with all the disgust of conscious superiority, upon the indifference of our forefathers to the first principles of sanitation and hygiene ; in a not distant to-morrow our long toleration of the smoke curse will be referred to as an example of the mingled patience and stupidity of the Georgian era. In this advance to cleanliness electrical development will play a necessary part.

Another conspicuous change will be in the street traffic. The horse will have practically disappeared, its place taken by silent, clean electric vehicles ; and the fast motor traffic, where it is not purely electric, will be carried on by vehicles with silent engines and electric transmission gear. Our critical successors will perhaps be as much impressed by our toleration of noise as with our indifference to the filth of smoke. It is certain, at any rate, that with a full use of electric road transport, the facility of easy and rapid locomotion can be enjoyed by a much larger section of the population without

transforming the streets into pandemonium. Railed traffic will, as a matter of course, be operated electrically throughout, giving services of high frequency and speed. All the city distribution of goods, heavy and light, will be undertaken by electric vehicles ; and this local service may be linked up with town-to-town transport by employing wagons on tractors which are able to run on battery power within the city and to take power from overhead trolley wires erected alongside the main routes between cities.

Above all, the electric city will be a city of light. If anything is probable about the future of electrical invention, it is that we shall attain a still more economical source of light than even the remarkably efficient lamps of to-day. And without that improvement the benefits of bright streets are becoming so widely appreciated that a rise in the standard of illumination is inevitable. It will no longer be looked upon as sufficient to provide just enough light for a moderate degree of safety and convenience. The object will be to render our thoroughfares, both in city and in suburb, so brilliant that the fall of night will cease to bring the depression of gloom which results from our present twilight standards. We have learned the effect of ample light upon the spirits of workpeople in factories and of dwellers in houses ; we have now to apply the same lesson to our thoroughfares.

There is perhaps no need to complete the picture of the electric city by references to the transformation of homes and factories. These have already been described in sufficient detail to enable anyone to realise that it is behind walls the most important changes will take place. Of all the gifts that electricity brings, almost the greatest is the relief from the burden of mechanical, monotonous, everlasting toil. Electricity has been appropriately called " the world's right hand," and its great function is to free human beings from the tasks which render them, even in this age of progress, so often beasts of burden. It is the hewer of wood and the drawer of water for the human race. Just as our factories have become reorganised to turn out their product rapidly and efficiently by electrical machinery controlled by man, our homes will be transformed to operate smoothly with the aid of electricity,

so that the labour now involved in cleaning, in heating, in cooking, and in washing and other domestic tasks will be performed by an electrical deputy. The energy thus released can be directed to the enjoyment of home life, to education, to the cultivation of music and art and the other beneficent recreations for which a measure of freedom is essential. Leisure will cease to be the monopoly of the well-to-do and will extend until it becomes a common possession.

Add to all these homely benefits the gifts of rapid transport from city to country and from city to city, of rapid communication over tens, hundreds, thousands of miles, of the manifold aids to the prevention and cure of disease, and one realises that electricity touches the betterment of humanity at innumerable points of domestic, social, civic, and national life. "This protean service," as is remarked in one of the publications of the British Electrical Development Association, "which has opened a happier era in the life of mankind, is the gift of science, of engineering, of corporate enterprise." It is fitting, therefore, that we should conclude upon a note of gratitude to the three groups which have co-operated in creating and developing this gift—to the men of science who worked in laboratories, little knowing what potent forces they were unlocking by their experiments ; to the engineers who designed and the manufacturers who constructed ; and to the companies and municipalities which devoted money and organising power to the spread of the supply of electricity. Those of us who have lived within the electrical industry for many years know how modest has been the material reward enjoyed by the members of any one of these groups ; but in service to their fellow-men they are rich beyond the dreams of avarice.

INDEX

- Accumulators or storage batteries, 13
- Aeroplanes, electrically driven, Capt. Durnall's suggestions, 38
- Agriculture, electricity in, 227
- Alternating current, "Faradic current" an electro-medical synonym for, 211
- Aluminium, uses of electricity in manufacture, 107, 168
- Amber, electrification by rubbing, 9
- Arc cutting and welding, 169
- Arc lamps, early installations, 1, 11, 12; flame type, 114
- Arc lights, efficiency of, 138
- Argon, the element present in the "gasfilled" electric lamp, 117
- Armstrong's, Sir William (afterwards Lord Armstrong), water-power plant in 1879, 54
- Atkinson, Llewelyn (President of the I.E.E., 1920-21), *quoted*, 110; reference to "seeing" at a distance, 220; reference to the "thermionic valve," 222
- Atlantic cable, first laid by the late Sir Charles Bright, 219
- Atomic character of electricity, 5
- Atomic energy, 110
- Auto-trolley, the, 32
- Automatic signalling, 26
- Automatic telephone exchanges, 220
- Automobiles, electrically propelled, 34
- Baths, electric "dry," 167
- Battery, Edison type, 41; for electric vehicle, 38; invented by Volta, 9; lead type, 41; medical, 10; voltaic, 10
- Bed-warmer, electric, 166
- Beeton, Mrs., *alluded to*, 176
- Board of Agriculture researches into effect of electricity on plant life, *referred to*, 227
- Board of Trade, *referred to*, 100, 106
- Bradford, trolley omnibuses in, (*illus.*), 33
- Bright, the late Sir Charles, laid first Atlantic cable in 1858, 219
- Brighton Beach Railway, 3
- British Aluminium Co., Ltd., hydro-electric installation, 107
- British Electrical Development Association, *referred to*, 233
- Broughams, electric, 40
- "Bulk" supply, the coming of the super station, 95
- Cables, early method of insulation, originated by Dr. Ferranti, 98
- Calcium carbide, use of electricity in manufacture, 168
- Carpets, electrically heated, 166
- Central heating and electricity, combination recommended for heating and cooking, 162
- Central power stations. (*See under* Power Station)
- Centralised power supply, economy and benefits of, in electric traction, 22; to the manufacturer, 79
- Chemical energy, conversion of, into electrical energy, 9; the storage battery, 14
- Chemistry, uses of electric power in, 171
- Chester, water-power plant at, 107
- City and South London Railway, the pioneer "tube," 25
- Civilisation, electricity as a factor in, 2
- Clothes-ironing machines, electric, 202
- Clothes-washing and wringing machines, 199-201
- Clothing, electrically heated, 166
- Coal-cutters, electric, 68
- Coal mining, electric safety lamp, 70; supremacy of electric power in, 67

- Coffee percolator, electric (*illus.*), 180, 182
- Colour matching by artificial light, the "Sheringham light," 144
- Comb, electric, 166
- "Concealed" lighting, 131
- "Concentrating" reflectors, 132
- Controllers, motor, 60
- Convectors, early type, 152
- Conveyers, overhead, 65
- Cooking, advantages of electricity in combination with central heating, 164; cleanliness and purity of electricity, 177; ease of control in electric, 177; electric, the ideal way, 173; grilling, 179
- Cooking appliances, electric: coffee percolator, 180, 182; electric grill, 180; hot plates, 177; small types for "lighting" circuits, 183; "immersion heater," 184; self-contained appliance, 184; standard size ovens, 174, 182; table appliances, 181; toaster, 181, 182
- Crane, electric, and lifting magnet (*illus.*), 62; overhead travelling, 65
- Crompton, Colonel, his example of "concealed lighting" at Buckingham Palace, *referred to*, 131
- Curling-tong heater, 166
- Decentralisation of industries assisted by electrical development, 229
- Decomposition of fluids (in medical treatment), 213
- Dee, River, hydro-electric installation on, 107
- Direct current, "galvanic current" an electro-medical synonym, 211
- "Direct" lighting, 131
- Dish-washer, the electric, 196
- Distillation of liquids by electric heat, 171
- Distribution, electrical, loss of energy in, 55
- "Diversity factor," application of the phrase, 78
- Domestic applications of electricity, cooking, 173; heating, 151; lighting, 119; some minor labour-saving devices, 188
- Domestic heating appliances, various, 159 *et seq.*
- Domestic lighting, 119 *et seq.*
- Drilling tools, portable, 66
- Durtall, Capt. William P., his association with electric system of ship propulsion, 37; suggestions for electrically driven aeroplanes, 38
- Dynamo, its reversibility, 21, 53; principles of construction and working, 11
- Edison storage battery, 41
- Edison, Thos. A., his faith in battery traction, 41; invention of incandescent (vacuum) lamp, 12, 221
- Egg-whisk, 204
- "Electric drive," advantages over steam, 61; "individual" v. "group," 85
- Electric heaters, an evolution from the incandescent lamp, 151
- Electric Lighting Act (1882), 3; its provisions, 14
- Electric Lighting (Amendment) Act (1888), 15
- Electric propulsion of ships, 37; adopted by U.S. Navy, 38; electric river launch, 40
- Electric traction. (*See also under* "Tramways" and "Railways") economy of centralised power, 22; most economical system of transport, 24; on railways, 25; on roads, 31; overhead runways, or "telpher" lines, one of the earliest applications, 65; pioneer undertakings, 3, 20
- Electric vehicle charging stations, 50-51
- Electric Vehicle Committee of Great Britain, constitution and objects, 41
- Electric vehicle, advantages and limitations, 42; broughams, 40; early history, 38; economy of maintenance and repairs, 49, 51; in local goods delivery service, 43; invalid chairs, 49; merits in taxicab service, 48; present limitation of range not permanent, 50; range of the touring car, 48; typical uses in municipal service, 42
- Electricity and magnetism, importance of Faraday's discoveries, 1-2

- Electricity Commissioners, *alluded to*, 52; powers and duties, 101; electricity areas delimited, 104
- "Electricity Districts," 101, 113; areas delimited by Electricity Commissioners, 104
- Electricity (Supply) Act, 1919, 15; its provisions, 101
- Electrification of railways and tramways, 20
- Electro-chemistry, 171
- Electro-magnet, 10
- Electro-magnetic machines, 10
- Electro-medical appliances: electric bath, 167; electric cautery, 216; electric vibrator, 216; local heating pads, 216
- Electro-medical treatment: effects of "static" and "high frequency" treatment, 212; "diathermy," 213; electric baths, 211; galvanic current for decomposition of fluids, 213; "iontophoresis"—conveyance of drugs to deep-seated tissues, 213; ultra-violet rays, a substitute for the sun-bath, 214; X-rays, 215
- "Electrodes," 167
- Electroliers, 128
- Electrolytic disinfecting fluid, 210
- Electro-metallurgy, 168
- Electromotive force, 96
- "Electrons," 110
- Electrophone, the, for transmission of music, etc., 222
- Energy, atomic, 5, 110
- Energy, electrical, its universality and established uses, 5; transmission of, 54
- Energy, mechanical, conversion to electrical, 55
- Engineering Standards Association, standard for electric ovens, 182
- Engines, oil, 105
- Engines, steam, 91
- "Extensive" reflectors, 132
- Factories, benefits of central power supply, 79; electrically-driven more efficient than steam-driven, 64
- Factory lighting, a special branch of illuminating engineering, 138
- Faraday, Michael, importance of his discoveries in electricity and magnetism, 1-2; *referred to by* Lord Kelvin, 2
- "Faradic current," electro-medical term for "alternating" current, 211
- Farm management, uses of electricity in, 225
- Ferranti, Dr., proposal for power transmission, 98
- Finsen, Professor, *alluded to*, in reference to "ultra-violet ray" treatment, 214
- Fires, electric: advantages over coal, 154; flexibilities of use, 155; small portable types for bathrooms, bedrooms, offices, etc., 157; their superiority in convenience and labour-saving, 156
- Flame arc lamps, 114
- Flash lamps, 10
- Flat-iron, electric, 165
- Fleming, Prof. J. A., *alluded to*, 9; reference to the "thermionic valve," 221
- Flood-light projector, 150
- "Flood-lighting," its decorative and commercial possibilities, 148
- "Focussing" reflectors, 132
- Force, electro-motive, 96
- Furnace, electric: a development of the electric arc, 167; uses in metallurgy, 168
- "Galvanic current," electro-medical term for "direct" current, 211
- "Gas-filled" electric lamps, 116
- Generating station. (*See under* Power Station)
- Generator, the dynamo, 11
- Giant's Causeway and Portrush, the first electric railway, 3
- Glasgow: diagram of daily load curve, 89; electric tramways in, 24
- "Glow" lamp, invention of, 13
- Goods transport, advantages of electric vehicles in local delivery, 44
- Graphite, use of electricity in manufacture, 168
- Grill, the electric, 180
- Grinding tools, portable, 66
- "Half-watt" lamps, discarded term for the "gasfilled" lamp, 117

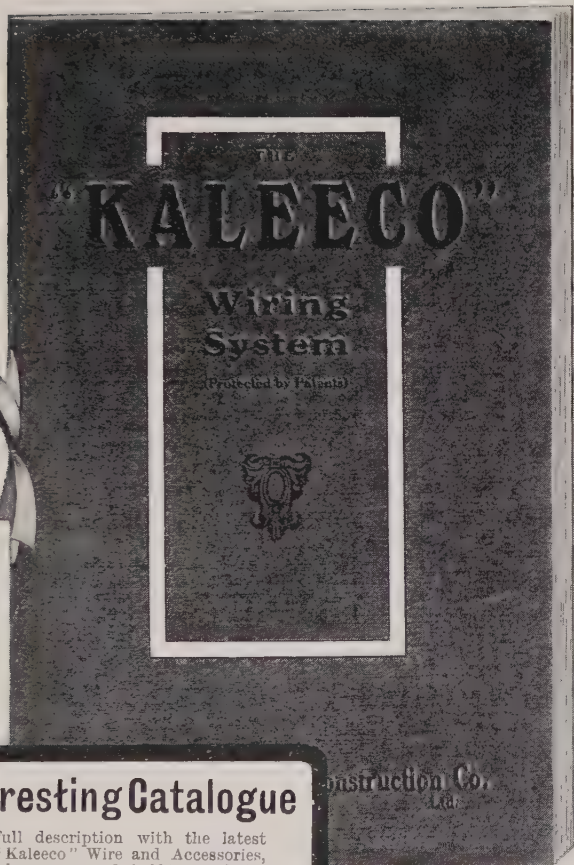
- Health preservation, specific services rendered by electricity in, 207
- Heating apparatus: low-temperature type, 167; various types of, 151
- Heating, electric: by convection, 152; by radiation, 152; in the home, 151; minor applications, 165; "thermostatic control," 171; woven elements applied to blankets, bed-quilts, clothing, etc., 166
- Heating pads, in medical treatment, 216
- Hereford, overhead mains at, 103
- "High frequency" applications in medical treatment, 212
- Hill, Dr. Leonard, researches in ventilation, 208
- Home, the ideal all-electric, cheaper to build and equip than ordinary house, 205
- Home Office Committee inquiry into subject of industrial lighting, 140
- Horse tramways, hindrances to electrification, 21
- "Hot plates" for cooking purposes, 177; for water-heating, 160; small types for "lighting" circuits, 183
- Hydro-electric development in Great Britain, 106; Severn schemes, 107
- Hydro-electric installations: British Aluminium Co., Ltd., at Foyers, 107; Chester Corporation on River Dee, 107; at Worcester, 107
- Illuminating Engineering Society, *referred to*, 125
- Illumination: the art and science of, 125 *et seq.*; requirements in factories, shops, and streets, 138 *et seq.*; requirements of the home, 119 *et seq.*; standard methods, "direct," "indirect," and "semi-indirect" (*illus.*), 133; stimulating effect of good lighting, 136; three essentials to good lighting, 126
- Immersion heaters: for cooking purposes, 184; for water heating, 159
- Incandescent (gasfilled) lamp, 116
- Incandescent (vacuum) lamp: first appearance in commerce, 3; first installation in Lord Kelvin's house, 13; invention of, 12; Osmium drawn metal wire filament, 114; tantalum drawn metal wire filament, 115; tungsten metal filament, 115
- "Indirect" lighting, 134
- Industrial applications of Electricity, 53
- Industrial heating: chemical processes, 171; electric furnace, 167; electric welding, 169; miscellaneous processes, 170
- Industrial lighting: in factories, 138; shops and windows, 141; electric signs, 147; "flood lighting," 148; inquiry and report by Home Office Committee, 140
- Industry, electrical, capital invested in, 4; its birth and rapid development, 3 *et seq.*; development of electric supply, 18 *et seq.*; restrictive effect of early legislation, 14
- Institution of Civil Engineers, discussion on dynamo improvements and electric transmission *alluded to*, 16
- Institution of Electrical Engineers, "wiring rules" *referred to*, 122
- "Intensive" reflectors, 132
- Invalid chairs, electric, 49
- Ironing machines, electrically heated and driven, 202
- Joint Electricity Authorities: their composition and objects, 101; Supplementary Bill *re Finance*, 102
- Kelvin, Lord: *alluded to*, 8; *quoted*, 10, 11, 13; reference to Faraday, 2; reference to transmission of electric energy, 16-17
- Kettle, electric, with attached heating element (*illus.*), 159
- Labour-saving in the home, the uses of electric light, heating, and cooking, 188
- Lamp fittings: electroliers, 128; standards, for table and floor, 128

- Lamps, arc, 1, 11, 12; efficiency of, 138; flame type, 114
- Lamps, Incandescent: as a source of radiant heat, 151; carbon filament, 114; flash, 10; metal filament, 114
- Lathes, automatic, 85
- Launch, electric battery, 40
- Lead type batteries, 41
- Legislation: Electric Lighting Act (1882), 3, 14; Amendment Act (1888), 15; Electricity Bill for financing joint electricity authorities, 102; Electricity (Supply) Act, 1919, 15, 101
- Lighting: advantages of electric light, 119; "concealed" lighting, 131; "direct" lighting, 131; disastrous effects of bad lighting, 140; essentials of good lighting, 126; first law of good lighting, 130; "flood-lighting," 148; in the home, 119; in factories, 138; in shops, 141; "indirect" lighting, 134; "semi-indirect" lighting, 135; stimulating effects of good lighting, 136; street lighting, 144
- Liverpool Overhead Railway, 25
- "Load curve": effect of the electric battery vehicle, 50; effect of industrial power demand (*illus.*), 87; the ideal, 19; lighting and industrial power charts, 89-90
- London "Safety-First" Council, suggested degrees of illumination for street lighting, 146
- Magnetic machines, 10
- Magnetism and electricity, 1, 10
- Magnetos, 10
- Magnets: electro or soft-iron, 10; permanent steel, 10
- Marconi's first apparatus, 221; first demonstrations, 3
- Measurement of electrical phenomena, 8
- Measuring and recording instruments, essential to accuracy and efficiency, 82
- Medical and surgical applications of electricity, 210
- Medical batteries, 10
- Mersey Railway, 26
- Metallurgical uses of electricity, 168
- Metropolitan District Railway, 26
- Miners' safety lamps, 70
- Ministry of Munitions, in control of electrical production during the War, 10
- Ministry of Transport, *alluded to*, 103
- Montagu, Lord, *alluded to*, 24
- "Moon-power," the energy of the tides, 107
- Motor controllers: automatic, 60; "push-button," 60
- Motor omnibuses, the trend of development, 47
- Motor, electric: capacity for overloads, 23; domestic uses of, 188; "individual" and "group drive," 85; minor industrial uses, 86; speed control of, 60; typical industrial applications, 71; unique for traction purposes, 21; unrivalled convenience of application, 72
- Multiple "unit" system on electric railways, 28
- Municipal services, electric-battery vehicles in, 42
- Nasmyth, James, his scheme of steam-power distribution, 56
- Oil fuel, 105
- Omnibuses: electric trolley, 32; petrol-electric, 36, 47
- Optophone, the, an instrument for reading ordinary type by sound, 221
- Osmium metal filament lamp, 114
- Oven, the electric, 174; standard sizes of, 182
- Overloads, capacity of electric motor for, 23
- Parsons, Sir Charles, the steam turbine chiefly due to, 92
- Permanent magnet, 10
- Petrol-electric vehicles, 34
- Pilkington Hospital (St. Helens): treatment of damaged limbs, 216
- Ploughing by electricity, 226
- Polishing machines, electric, 202
- Power plant installations, the problem of maximum demand, 77
- Power, sources of: atomic energy, 110; chemical energy, 14; oil

- fuel, 105; steam, 55; sunlight and solar engines, 109; tidal water, 107; water power, 105; windmills, 109
- Power station: evolution and growth, 12; effect of battery vehicle load, 50; effect of industrial power development, 86; introduction of tramway load, 19; super station, 95 *et seq.*; site requirements of the "super station," 111
- Power supply, the benefits of centralisation, 76 *et seq.*; economy of centralised power in electric traction, 22; in bulk, 95
- Power transmission: the birth of an industrial revolution, 54; Lord Kelvin's forecast, 16; mechanical *versus* electrical, 55; Dr. Ferranti's achievement, 98; Parliamentary opposition to early schemes, 99; reasons for high voltage, 96
- Prices for electric current: reason for low rates for heating and cooking, 159; for vehicles, 51
- Prismatic reflectors, 131
- Radiators, electric, early type evolved from the carbon lamp, 151
- Radium, an example of the "atomic system," 5
- Railless electric traction, 32
- Railways: benefits of main-line electrification in rural development, 104; Brighton Beach Railway, 3; City and South London Railway, 25; Giant's Causeway and Portrush, 3; incentives to electrification, 25; Liverpool Overhead Railway, 25; Mersey Railway, 26; Metropolitan District Railway, 26; multiple "unit" system, 28
- Ramsay, Sir William, discovery of argon, *referred to*, 117
- Reflectors: standard types "extensive," "intensive," "concentrating," and "focussing," 132; use in improvement of direct lighting, 131
- Refuse collection by electric vehicles, advantage of, 42
- Resistance, law of, 12
- Riveters, portable electric, 66
- Road trains, 36; advantages of electric transmission, 37
- Road transport: economy and efficiency of electrics for local goods transport, 44; electric tramways, 24
- Roads, electric traction on, 24, 31
- Rural development: benefits of railway electrification, 104; power transmission at Hereford, 103
- Rural industries, electricity as a factor in development, 228
- "Safety-first," the importance of adequate street lighting, 144
- Sanitation and hygiene, prospects of progress in, 231
- Selenium cells, action of, in transmitting light, 220
- "Semi-indirect" lighting, 135
- Severn, river, water-power scheme on, 108
- Sewing machine, electrically driven, 204
- Shanghai, trolley omnibuses in, 32
- Sheringham, George, the "Sheringham light" for colour-matching, 144
- Ship, electric, 37
- Shop lighting, 141; effective window display, 142
- Siemens, Dr., reference to electrical transmission, 16
- Signalling, automatic, 26
- Signs, electric, 147
- Sims, George R., *quoted* in reference to street lighting, 144
- "Solar engines" and sunlight as a source of power, 109
- Speed control, efficiency of, with electric motors, 61
- Spring-cleaning, the electrical way, 191
- "Static," applications in medical treatment, 212
- Steam power: comparison with electric power, 55; waste of energy in, 56
- Steam railways: destined to be electrified, 31; incentives to electrification, 25
- Steam turbine, responsible for great development in electrical generation, 92
- Steel hardening and tempering, use of electric furnace in, 168

- Sterilising by exposure to "ultra-violet rays," 209
- Storage, or secondary, batteries, nature of, 13
- Street lighting, 144; London "Safety-First" Council's suggested degrees of illumination, 146
- Structural steel work, electric welding in, 170
- "Subdivision of the electric light," 12
- Submarine telegraphy, 219
- Suction cleaner, the electric (*illus.*), 193
- Swan, Sir Joseph, invention of incandescent (vacuum) lamp, 12
- Switches and switching, suggestions for arrangement and control, 122; the "time switch," 161
- "Table cookery," electric appliances for, 181
- Tank heaters, electric, 162
- Tantalum metal filament lamps, 115
- Taxicabs, the advantages and scope of battery traction, 48
- Telegraph, electric, its influence on world history, 218
- Telegraph, the submarine, 219
- Telegraph instruments first used on railways, 218
- Telegraphic signalling, development of high speed in, 219
- Telegraphy, an unsolved problem in, 220
- Telegraphy, wireless: Marconi's experiments, 3; the "thermionic valve," 221; time signals, 222
- Telephone: automatic exchanges, 220; hampered progress of the, 220; invention of, 3
- Telephony, wireless, 222
- "Telpher" lines, 65
- Tempering wire by electric heat, 170
- Thermionic valve, the, 221
- "Thermostatic control" in electric heating, 171
- Thompson's, Silvanus P., *Life of Lord Kelvin*, quoted, 16
- Tidal water power, 107
- Toaster, electric (*illus.*), 181, 182
- Tools, portable electric, 66
- Tramways Act, 1870, 20
- Tramways, electric: in Glasgow, 24; method of taking current, 32; obstacles to early electrification, 21
- Transformers, the use of, 96
- Transmission of light by telegraph and "wireless," 220
- Transmission of power: birth of electrical, 54; mechanical *versus* electrical, 55
- Transporter, electrically driven (*illus.*), 63
- Trolley omnibus systems, 32
- "Tube" Railway, City and South London Railway, 25
- Tungsten metal filament lamps, 115
- Tunzelmann's *Electricity in Modern Life*, referred to, 54
- Turbine generating sets, development of, 92
- "Ultra-violet rays," 209; in medical treatment, 214
- Vacuum electric lamps. (*See under* Incandescent (vacuum) lamps)
- Vacuum or suction cleaner, the electric, 192
- Variable speed motors, 60
- Vehicles: electric storage battery, 38; petrol-electric, 34
- Ventilating fans: desk type, "Port-hole" type, and "punkah" or ceiling type (*illus.*), 209; in mines, factories, and large buildings, 207; oscillating type for domestic use, 208
- Ventilation, in theory and practice, 207
- Vibrator, electric, 216
- Volta's battery, 9
- Voltage, meaning of the term, 95
- Water-heating: apparatus for large quantities, 160; apparatus for small quantities, 159; combination of central heating and electric heating recommended for large and constant supply, 162; the immersion heater, 159
- Water power installations, 54, 105-107
- Water-power Resources Committee: River Severn Schemes, 108; survey of field for hydro-electric development, 106
- "Watt," the unit of electrical energy, 118

- Watt, James, and the invention of the steam engine, *alluded to*, 54
- Welding, electric: "arc" and "resistance" methods described, 169; "cutting arcs," 170; in structural steel work, 170
- Winding-gear, for coal mines, 68
- Windmills as a source of natural energy, 109
- Window lighting, an object lesson in "stage effect," 143
- Wireless telegraphy: Marconi's demonstrations, 3; the "thermionic valve," 221; time signals for navigation and "master clock" control, 222; underlying principle of operation, 221
- Wireless telephone: development of, 222; transmission of music 222
- Wiring rules, 122
- X rays, 215



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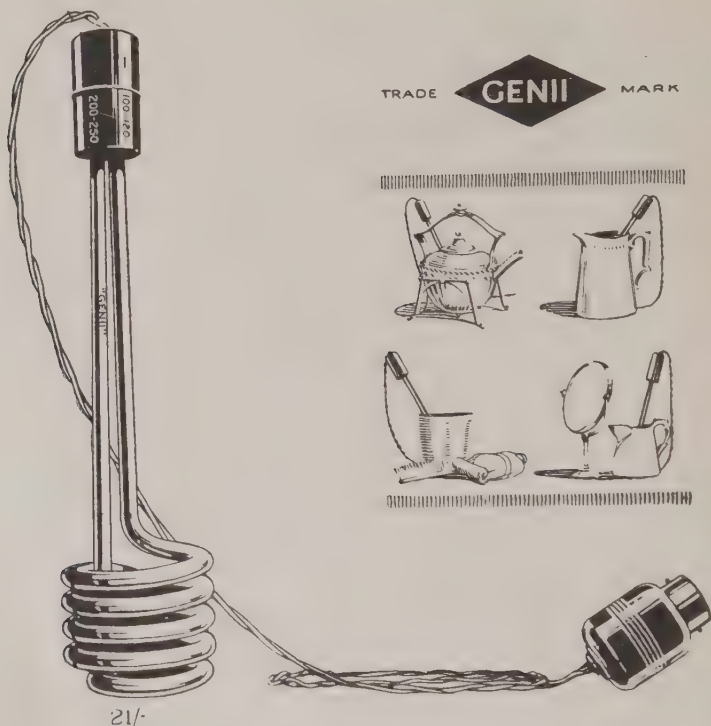
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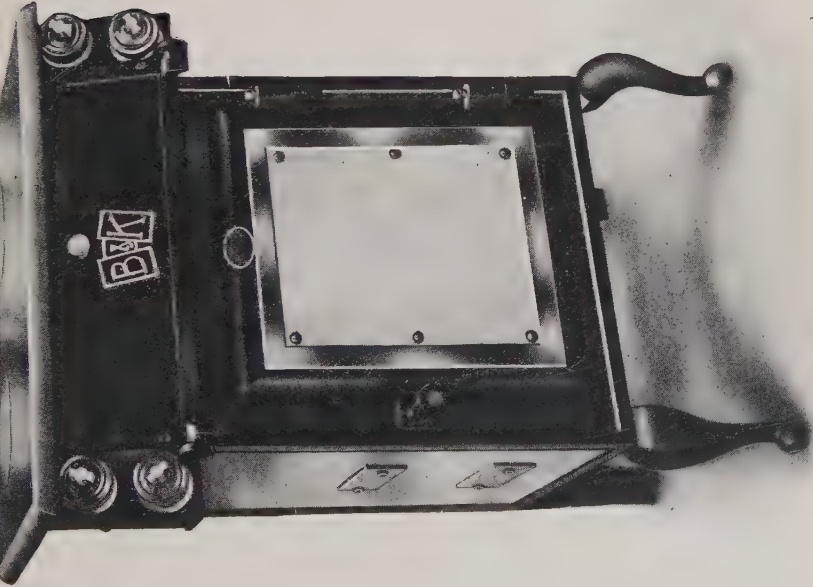
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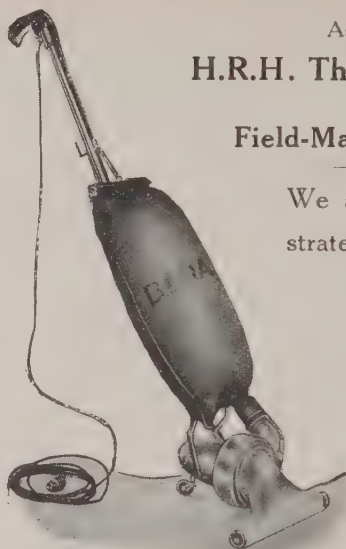
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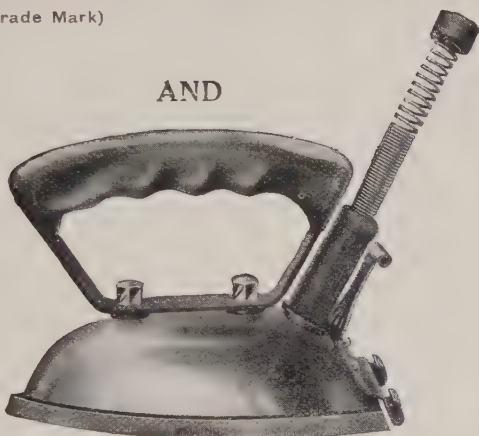
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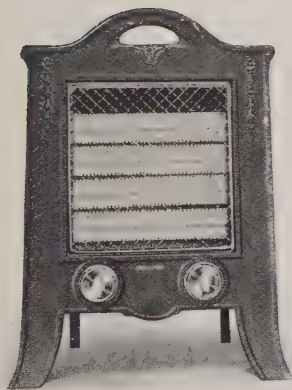
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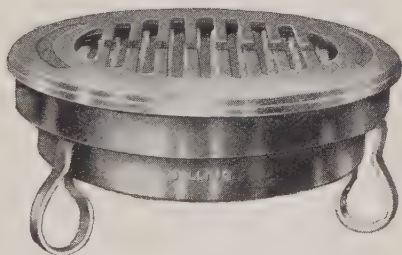


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